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ABSTRACT

Despite its cold and barren appearance, Alaska's tundra supports a surprising variety of insects, birds, and mammals. In this document, three teacher's guides (for primary, upper elementary, and junior and senior high schools) and a supplementary resource packet present a comprehensive unit of study on Alaska's living tundra. The five lessons in each guide cover the nature of tundra environments, types of tundra and the organisms present, special survival adaptations of tundra wildlife, interconnections of the tundra ecosystem, and human use of and effects on the tundra. Guides include teacher background information, a glossary, classroom activities, ideas for curriculum integration, worksheets for student review or evaluation, and references. Class activities develop or improve students' skills and knowledge in science, social studies, language arts, mathematics, or art. The supplement contains summaries of information about permafrost, topography of the tundra, and tundra wildlife, as well as over 100 wildlife cards with illustrations and text, presenting the most common or easily recognized plants, animals, fungi, and microscopic organisms found in Alaskan tundra. (SV)

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Alaska's Living Tundra

Primary Teacher's Guide

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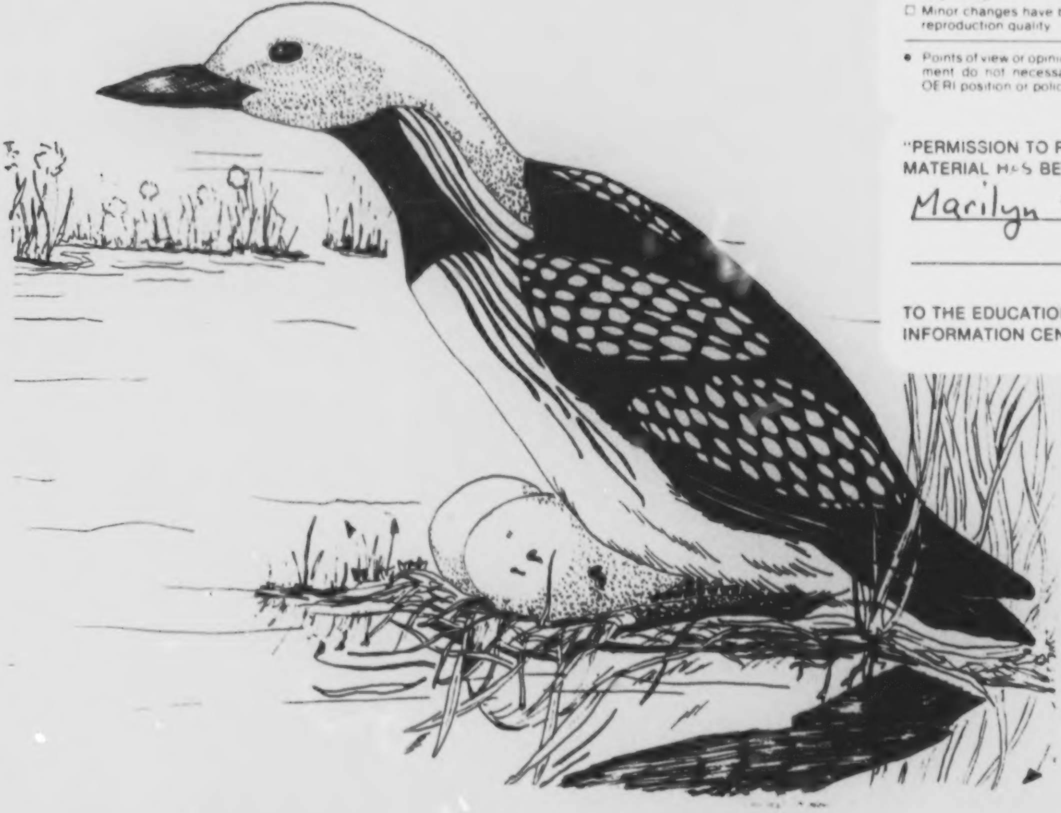

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Alaska Wildlife Week 25-29 April 1988 **Unit 6**

Alaska Department of Fish and Game--Nongame Wildlife Program--Game Division

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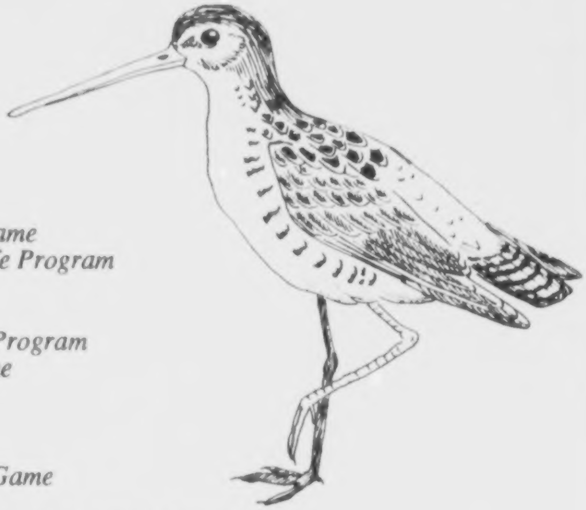
Alaska Wildlife Week 1988
Unit 6. Alaska's Living Tundra



Educational Packet:
Teacher's Guide
Wildlife Photo Poster
Tundra Wildlife Cards
Alpine and Lowland Tundra Posters

Published by: Alaska Department of Fish and Game
Game Division--Nongame Wildlife Program

Written by: Susan E. Quinlan
Game Division--Nongame Wildlife Program
Alaska Department of Fish and Game

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Introduction

Imagine a wetland that is really a desert. A place where animals find warmth on hills of ice. Imagine a place where 100 year-old plants are only a few inches tall. A place where billions of insects, millions of birds, and hundreds of thousands of mammals swarm, but where visitors often see nothing. Imagine an environment of contrasts. Imagine Alaska's tundra.

Many people think tundra is cold, barren, and desolate. Perhaps at first glance it is. On closer investigation, however, one finds that tundra environments are among the most fascinating in the world, and that a surprising variety of wildlife not only survive in tundra environments, but also flourish.

Discover this environment with your students as you use this **1988 Alaska Wildlife Week Educational Packet.** This comprehensive unit on **Alaska's Living Tundra** includes: A **Teacher's Guide**--full of background information on Alaska's alpine and lowland tundra environments, interdisciplinary activities, games, and worksheets; **A Wildlife Poster**--with color photographs of 12 species of tundra wildlife and two types of tundra; a set of **Tundra Wildlife Cards**--illustrations of and text about over 100 kinds of organisms that live in tundra environments; and **Tundra Posters** depicting many of the wildlife of Alaska's alpine and lowland tundra.

The Teacher's Guides are organized so that each of the 5 lessons on tundra builds upon those previous. An introductory activity is suggested for each lesson; use these along with any of the the wide variety of Activities for Curriculum Integration that are provided. The thematic approach of the packet is intended to help instructors integrate the study of tundra with regular classroom curriculums. All the activities are designed to help students develop or improve their skills and knowledge in science, social studies, language arts, math, and/or art. Easy-to-duplicate worksheets may be used to review, reinforce, or evaluate student understanding of the lessons in this unit.

Please feel free to adapt and modify activities and worksheets to best suit your teaching style, students' learning styles, and your location and situation. Three separate Teacher's Guides were prepared--one each for Primary (K-3), Upper Elementary (4-6), and Junior/Senior High School. Check to be sure you have the one that best matches your students' knowledge and thinking skills.

As always, we encourage you to integrate Alaska Wildlife Week with other conservation education materials available in Alaska. The Reference List at the end of this guide provides a list of many teaching materials relevant to this unit on Alaska's tundra. (This year, a special cross-reference to the Project Wild materials is included since many Alaskan teachers are also using those materials. See the information provided in the Reference List.)

The Alaska Department of Fish and Game began producing the Alaska Wildlife Week materials in response to teacher requests for Alaska-specific materials on wildlife and conservation. This project was orignally patterned after the National Wildlife Week educational effort sponsored by the National Wildlife Federation. **1988 marks the sixth year of Alaska Wildlife Week.** The theme for this annual celebration has changed each year, and a separate packet on each of six themes have been developed. You will find that the packets developed in previous years have some information and activities relevant to this year's topic. Check your school library for copies.

We hope you will use these materials during Alaska Wildlife Week in 1988, as well as throughout this and other years. Please send any comments or suggestions about this project to: Alaska Wildlife Week, Alaska Dept. of Fish and Game, Nongame Wildlife Program, 1300 College Road, Fairbanks, AK 99708

ALASKA WILDLIFE WEEK.

Primary Teacher's Guide

UNIT 6. Alaska's Living Tundra

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Lesson / Objective	Teacher Background	Introductory Activity	Ideas for Curriculum Integration	Student Worksheet
1. TUNDRA ENVIRONMENTS Students will learn what tundra is and why it exists only in certain areas.	7-8	9-14	16-18	19
2. THE LIVING TUNDRA Students will identify different types of tundra and the organisms present.	20-21	22	23-25	26-28
3. ADAPTATIONS OF TUNDRA LIFE Students will learn about the special traits organisms have to survive in tundra areas.	29-34	35	36-44	45
4. TUNDRA CONNECTIONS Students will learn about the ways the tundra ecosystem is interconnected.	46-49	50-57	58-61	62-63
5. HUMAN USE OF THE TUNDRA Students will recognize that humans can affect the tundra.	64-66	67	68-70	71

Supplementary Materials That Accompany This Teacher's Guide

A Color Poster

Color photographs of Alaska's lowalnd and alpine tundra and 12 kinds of tundra wildlife

Tundra Wildlife Cards

Over 100 illustrated cards of common tundra wildlife of Alaska, including birds, mammals, insects, invertebrates, fungi, plants, and microscopic organisms.

Adaptation Cards

Thirty-two illustrated cards with information about animals and their adaptations to various environments.

Alpine and Lowland Tundra Posters

Two pen and ink illustrated posters depicting alpine and lowland tundra environments and wildlife.

Worksheet Answers

Worksheet 1. Top left, center right, and lower left should be underlined as these show tundra environments.

Worksheet 2a. ground squirrel, Dall sheep, mountain goat, golden eagle, snow bunting, wolverine, pika, ptarmigan, marmot

Worksheet 2b. 1. tundra hare, 2.arctic fox, 3. plover, 4. caribou, 5. lemming, 6. goose, 7. snowy owl, 8. muskoxen; the words at the bottom are "lowland tundra."

Worksheet 2c. self-explanatory

Reading Comprehension Worksheet:
Lemming: 1. mammal, 2. the tundra, 3. cold temperatures, 4. adaptations, 5. short tail, small ears, shovel-like claws, and white winter fur.
Tundra Plants: 1. a plant, 2. the tundra, 3. cold temperatures and wind, 4. adaptations, 5. hair, dark flowers, small size, and flowers that turn to face the sun;
Whimbrel: 1. a bird, 2. in the north, 3. fly, 4. adaptations, 5. migration, eggs that match the lichens and plants
Insects: 1. eggs, 2. dark, 3. antifreeze, 4. adaptations, 5. bumblebee.
Ptarmigan: 1. two, 2. to keep them warm and as snowshoes, 3. brown, 4. adaptations, 5. burrow under the snow

Worksheet 3. The following should be circled, right picture, right picture, right picture, left picture.

Worksheet 4a. The following are producers: sedge, crowberry, willow, moss campion--these should have circles around them. The following are herbivores: muskox, lemming, ground squirrel, midge--these should have squares around them. The following are carnivores: wolf, jaeger, wolverine, sandpiper--these should have triangles around them. The remaining organisms are detritivores and should have lines drawn under them: carrion beetle, springtail, fungi, bacteria.

Worksheet 4b. Connect the following: bumblebee to flower with nectar, ground squirrel to flower that needs minerals, ravens to wolves, fungi to heather.

Worksheet 5. Gee Whiz Tundra Quiz: 1. F, 2. T, 3. T, 4. T, 5. T, 6. F, 7. F (thousands do), 8. T, 9. T, 10. T, 11. F (the roots grow outward, but cannot grow deep into the soil due to permafrost), 12. T, 13. F, 14. F, 15. T, 16. F, 17. F, 18. F, 19. T, 20. T, 21. F, 22. T.

A Tundra Glossary

active layer	the layer of soil, lying on top of permafrost, that thaws and re-freezes each year
adaptation	a trait that enables an organism to survive in a particular environment
alpine tundra	periodically cold, treeless environments that occur at high elevations throughout the world
animal	living things in the Kingdom Animalia; one of the 5 major groups of living things that includes invertebrates (insects, crustaceans, worms, echinoderms, etc.) and vertebrates (birds, mammals, fish, amphibians and reptiles) Animals have a highly organized cell structure; most move from place to place, and all are consumers.
antifreeze	a compound that lowers the temperature at which water, or another liquid (such as sap, cell fluids, or blood) freezes
carnivore	a consumer that mainly eats other consumers; "carnivore" literally means meat-eater, and is usually applied to animals such as wolves, but organisms that eat mainly insects are also carnivores, since insects are consumers.
commensalism	an interaction between two species from which one species benefits and the other is unaffected
consumer	any living thing that gets energy and minerals by eating (consuming) other living or dead things
decomposer	an organism that breaks down dead organic material, thus returning minerals to the non-living environment (includes some micro-organisms that break down dead material without consuming it.)
detritivore	any consumer that ingests wastes and/or the remains of living things that have died; detritivores are a type of decomposer
dormancy	a period of inactivity, in which some or all life processes slow down or stop
ecosystem	all the non-living and living things and their interactions in a specific area
elevation	the height of the ground above sea level
energy	the force that causes objects to move; energy occurs in several forms including in light, heat, and stored in chemical bonds
environment	all the non-living and living things in a particular place
food chain	the pathway of energy and minerals from the non-living environment through producers and consumers back to the non-living environment
food web	all the inter-connected food chains within a particular ecosystem
frost boil	an area of bare soil up to several yards (meters) in diameter caused by repeated freezing and thawing of soil
fungi	one of the 5 major groups of living things. Most fungi do not move around, but instead, live their lives in one place. Most obtain minerals and energy from dead things and waste materials, but some obtain food through symbioses with plants or microscopic organisms. This group includes mushrooms, toadstools, shelf fungi, molds, yeasts, and rusts. (Slime molds are sometimes classified as fungi also.)

herbivore	a living thing that feeds on producers, such as plants, algae, or lichens
hibernation	a period of inactivity, in some mammals, during which all life processes (breathing, heart rate, body temperature, etc.) are reduced; an adaptation to avoid periods of cold and scarce food.
ice wedge	a wedge-shaped lens of pure ice in permafrost soil, caused by a crack in the permafrost that accumulates meltwater during summer; as the accumulated water freezes, an ice wedge grows. Ice wedges are the cause of polygonal ground in lowland tundra
insulation	anything that reduces the movement of heat energy into or out of a particular object or area
irruption	a sudden, large increase in the population density of a particular species in a given area
latitude	a measure of the distance of a given point on earth from the equator
life cycle	the birth, growth, reproduction, and death of a particular kind of living thing
living things	something that is able to move, grow, and make new things like itself; an organism. LIving things are classified into 5 major groups: animals, plants, fungi, monerans and protists.
lowland tundra	the cold, treeless environment found in the arctic and maritime subarctic
migration	a regular, seasonal movement of an animal from one place on earth to another
moneran	one of the 5 major groups of living things; includes only microscopic organisms, including bacteria and cyanobacteria (formerlly called blue-green algae). The cells of monerans do not have a nucleus.
mutualism	an interaction between two species from which both benefit; a type of symbioses
non-living	Something that does not, and cannot, move, grow, or make new things like itself; air, water, soil and rocks, and energy are the non-living things found in all ecosystems
parasitism	an interaction between two species from which one, the parasite, benefits, and the other, the host, is harmed; a type of symbiosis
omnivore	a consumer that eats both producers and other consumers
permafrost	perennially frozen ground that may or may not contain ice. In the arctic tundra permafrost may extend 2,240 feet (700 m) below the surface
pingo	an ice-filled hill on the tundra, sometimes 230 feet (70 m) or more high and 2000 feet (600 m) in diameter; a pingo may be circular, oval, or irregular in form
plants	One of the 5 major groups of living things; includes mosses, ferns, horsetails, conifers and flowering plants; this group is characterized by having cell nuclei and cell walls, a highly organized arrangement of cells, most can do photosynthesis and are important producers; most are green, and all except mosses and liverworts have a specialized system for transport of water and minerals, including roots, stems, and leaves.

polygons	one of the forms of patterned ground characteristic of soil subject to intensive frost action; many polygons are formed by ice wedges; polygons with sunken edges are called high center polygons; those with raised edges and a sunken center are called low center polygons
population	all the animals of a particular species that live in a particular area and interbreed
producer	any living thing that can convert non-living materials (air, water, and light) into food for itself and other living things; plants and algae are examples of producers
productivity	the amount of new growth, or number of young, produced per year or other unit of time
protists	any living thing in the Kingdom Protista, one of the 5 major groups of living things that includes some microscopic living things (algae and protozoans) and kelp or seaweeds; organisms in this group are characterized by their cell structure, which includes a cell nucleus, and by the lack of cell specialization for specific purposes
symbiosis	an interaction between two species in which at least one species depends upon the other
tundra	the windy, treeless, and periodically cold environments that occur at high latitudes and at high elevations
tussock	a small mound formed by certain tundra grasses that continually retain their dead leaves; walking is difficult across tussock tundra; tussocks are used by many kinds of insects and other tundra wildlife

Lesson 1.

Objectives:

Students will be able to describe the characteristics of tundra environments including the absence of trees, long cold winters and short cool summers.

Teacher Background:

WHAT IS TUNDRA?
The word"tundra" is derived from a Finnish word "tunturi" which means completely treeless heights. The absence of trees is an important characteristic of tundra, but deserts, prairies, and most wetlands are also treeless. The term "tundra" is used to describe the treeless ecosystems that develop in areas with long, cold winters and short, generally cool summers. Permanently frozen ground (permafrost), low precipitation, and persistent winds are important features of some, but not all, tundra environments.

Many people associate the term "tundra" with flat, featureless landscapes. But flatness is not a characteristic of tundra. Tundra occurs on flat plains, on rolling hills, and on precipitous mountain slopes just as do forests, deserts, and prairies. Additionally, many of the tundra areas that appear flat at first glance have surprisingly textured surfaces.

WHERE DOES TUNDRA OCCUR?
Periodic cold temperatures, and thus tundra environments, occur at high latitudes (near the north and south poles of the earth) and at high elevations throughout the world. Most of the tundra on earth occurs in the northern hemisphere because at high southern latitudes, the earth's surface is mainly covered by ocean.

WHY ARE THESE REGIONS COLD?
High Latitudes. Sites near the poles of the earth are cold because they receive less light and heat energy from the sun than do other areas of the earth. This occurs for two reasons. First, the earth tilts 23 1/2° on its axis, and so, in its annual rotation around the sun, each pole alternately tilts toward and away from this primary source of heat and light energy. Lands at northern and southern latitudes have days and nights of unequal length during most of the year. In June, the north pole is tilted toward the sun, so our days are long and nights are short. In December, the north pole is tilted away from the sun, so our nights are long, and days are short. Lands above the arctic and antarctic circles receive no sunlight during 2 months of winter, and little during the entire 6 months when the north pole is tilted away from the sun. In contrast, sites nearer the equator receive constant amounts of sunlight year round (day and night are of equal lengths).

Secondly, at high latitudes, even during the sunlit portion of the year, the sun is low on the horizon rather than overhead. The sunlight that reaches the earth's surface travels through more atmosphere and is spread over a larger area than at more southern latitudes. It therefore delivers less heat and light per unit area per hour.

At high latitudes, winters are long and cold, and summers are cool because of the seasonal tilt away from the sun of each pole, in combination with the low angle of the sun above the horizon during sunlit seasons. At Barrow, Alaska average daily temperatures drop below freezing in September, and remain so until May. From December through March, the temperatures ranges from -20° F (-28° C) to -16° F (-26° C) . At this high latitude site, the sun drops completely below the horizon on 18 November and does not rise again until 24 January.

High Elevations: Cold temperatures occur at high elevations for a different reason. At high elevations, the atmosphere is thin and contains little moisture, so little sunlight is reflected by particles in the air, and much more light and heat energy reach the ground than at low elevations. At first glance, then, it may seem surprising that cold temperatures, and thus tundra environments, occur at high elevations at all latitudes--even at the equator. The reason for this is that carbon dioxide and water vapor in the atmosphere act like a

Vocabulary:

cold, climate, environment, latitude, permafrost, temperature, treeless, tundra, winter

blanket of insulation around the earth--by reflecting back, or trapping, heat energy. At low elevations, a thick, dense blanket of moist air traps much of the heat that reaches the ground. But at high elevations, the thin air over the mountaintops traps little heat, and provides little insulation fromthe -50°F (-45.5°C) temperature of the upper atmosphere. High elevation sites may have warm temperatures during the day when the sun is shining, but most of the heat is quickly lost when the sun goes down at night. On high mountains, night-time air temperatures are often 54° F (30°C) colder than those at mid-day. Average air temperatures drop 3° F (-1.7°C) for every 1000 feet (305 m) increase in elevation. Thus, when the air temperature is 32° F (0°C) at the base of Mt. McKinley, the temperature on top (20,000 feet) is 60° F colder, or -28° F (-34°C).

WHY IS THE TERM "PERIODIC" IMPORTANT: If the severe cold of northern winters and alpine nights was continuous, living things could not survive. The change from cold, nearly unlivable conditions to cool, milder ones more suitable for living things is thus an important characteristic of tundra environments. The periodic change from severe cold to milder conditions occurs seasonally (winter to summer) in most tundra environments. As one moves closer to the poles of earth, the mild season becomes shorter, and so does the number of kinds of living things that can survive. In high elevation tundra environments near the equator there is no seasonal change in temperatures, but warm (even hot) temperatures occur every day, while bitter cold occurs each night. Thus the term "periodic cold" applies to these environments, too.

PERSISTENT WINDS: Persistent winds are a feature of some, but not all tundra environments. They occur in coastal polar regions and at high elevations for basically the same reasons. Winds are the movement of air masses from one one place to another. They are caused mainly by differences in air temperature from place to place, and by the rotation of the earth. Cold air tends to sink, while warm air rises. When an air mass moves, other air must flow in to replace it. The temperature of a given air mass is determined by many factors, including the intensity of solar radiation, the varying reflectivities and temperatures of the surface over which the air passes, and the watervapor content of the air. Winds at high elevations are caused in part by differences in the air temperatures on mountaintops and in valleys. Because air masses can pile up on one side of a mountain, and large differences in air temperature can occur between high and low elevations, winds in mountainous areas are more severe and persistent than anywhere else. As an example, winds of 45-65 mi per hr (74-105 km / hr) with gusts of up to 100 mi per hr (161 km/hr) are common on Mt. McKinley, even in summer. Winds in coastal polar regions are caused in part by variations in the temperature of air masses over ice, water, and land, along with the rotation of the earth.

Even in tundra areas where the occurrence and strength of winds are similar to those of mild environments, the cooling and drying effects of wind are intensified because of the absence of trees to block it.

LOW PRECIPITATION: Tundra regions have been called "cold deserts." However, the amount of precipitation that occurs in tundra areas varies greatly. Tundra in the far north receives less precipitation than some deserts [less than 2 in (5 cm)] and thus deserves the name. But some tundra regions of southwestern Alaska receive over 40 in (102 cm) per year, and some alpine tundra areas of Alaska receive 80 in (2 m) of precipitation each year!

PERMAFROST: Permafrost, or perennially frozen ground, underlies all tundra areas (except large lakes and rivers) in the far north. In western and southwestern Alaska, and in Alaskan mountains, it is discontinuous (patchy). In the Aleutian Islands, and on mountaintops at more southern latitudes, permafrost is absent, or rare. However, seasonal and/or nocturnal frostsoccur in all tundra soils.

Permafrost, when present, and seasonal frost both play an important part in shaping tundra lands and ecosystems. Some surprising topographic features of tundra are created by permafrost and frost action. See the Tundra Wildlife Cards section of this packet for photos and descriptions of these features.

Introductory Activity 1.

Objective:

Students will be able to picture a tundra environment and will recognize that the tundra has long, cold winters, wind, and no trees.

Skills:

LANGUAGE ARTS: Listening, memory, visualization; ART: drawing, illustration

Materials:

"The Story of Dicrostonyx torquatus, The Collared Lemming" (this packet), pictures of tundra animals (from this packet or other resources); pencils or pens, crayons or paints, butcher paper, tape

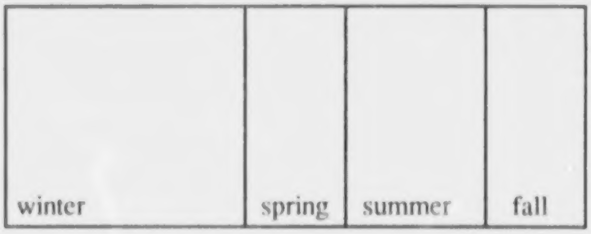
Procedure:

SUMMARY: After listening to chapters of a story about lowland tundra animals, students will draw pictures of the environment and animals described.

1. INTRODUCE THE STORY TO STUDENTS: Explain to students that you have found a story about some Alaska animals. Since the story does not have any pictures they will have to listen carefully and use their imaginations to picture the places and animals in the story. Later, they will help illustrate the story. Explain also that it is a story that has chapters, so you will be reading a new part of the story each day. Tell them that the story is about an animal that scientists have named Dicrostonyx torquatus. You may want to write this out on the board and explain that scientists have given all animals long names such as this. These scientific names are derived from Latin and Greek and are used so that scientists all over the world, no matter what language they speak, will know what animal other scientists have written about.

2. READ THE FIRST SECTION OF THE STORY. Read the first part of the story, which discusses the winter season on the tundra.

A Tundra Mural



3. DISCUSS THIS SECTION OF THE STORY. After reading the first chapter of the story, ask students to name and describe the place where the animals in the story live. Ask students the following questions: Was the place where the story occurs flat, or mountainous? Do trees grow there? What season was it during this chapter of the story. Was this season hot or cold? Does the wind blow a little, or a lot at the place described? Is the season light or dark? Is the ground warm or cold? What was the name of the place described in the story? What were some of the animals in the story?

4. STUDENTS ILLUSTRATE THE PLACES, EVENTS, AND ANIMALS IN THE STORY. Hang up a long stretch of butcher paper on a wall, or lay it on the floor so students can easily work on it. Divide the paper into 4 sections to represent the 4 seasons described in the story. (To show the relative length of the seasons on the mural, make the winter section very long, the spring and fall quite short, and the summer a bit longer than spring or fall.) Have students work together to make a large picture of the place and season described in the story. They should show the animals and/or events described in the story. If desired, you might encourage students to use reference materials, such as the Alaska Wildlife Week Tundra cards and poster, and books about Alaska animals and environments as references to make their illustrations more realistic.

5. REPEAT THE ABOVE STEPS UNTIL YOU HAVE COMPLETED THE STORY.

6. USE THE MURAL TO DISCUSS THE TUNDRA ENVIRONMENT AND ITS SEASONS.

Evaluation:

Have students complete Worksheet 1.

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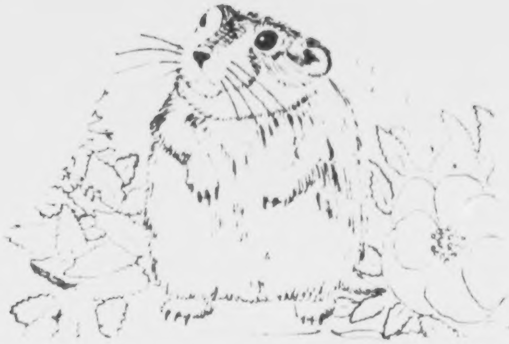


The Story of *Dicrostonyx torquatus* The Collared Lemming

by Susan E. Quinlan

CHAPTER 1. WINTER--A WORLD TO DISCOVER

Dicrostonyx torquatus, or Di for short, was a collared lemming. She lived on the tundra in northwestern Alaska. On the day she was born, the temperature was 30 degrees below zero and the tundra was frozen under a blanket of snow. Icy winds howled through the dark winter air. Tiny Di and her litter mates (brothers and sisters) were born with their eyes still closed and with no hair. They would have frozen in the cold air. Instead, they were warm inside a nest of grasses that their parents had built beneath the snow. The tiny lemmings slept and drank milk from their mother. Slowly they grew soft fur and opened their eyes.

One day Dicrostonyx was suddenly wakened by a pinch on the back of her neck. She squirmed and twisted only to find that she was hanging from her mother's mouth. A terrible smell filled the air of the nest. That horrible smell and her mother's strange actions made Di feel very afraid. She hung limp as her mother carried her out of the warm nest. Her mother then ran down a long, dark tunnel. Di's back end and feet felt icy cold when they brushed against the sides of the tunnel. Di sensed that her mother was scared too. Her mother hurried through one tunnel, then another. Finally she dropped Di inside a new grassy nest and then left. Di fluffed her fur out and curled into a ball to keep warm.

Di's mother returned in a few minutes. She dropped the littermate that she carried, then stopped. She listened carefully and sniffed the air. Di did the same. She heard the wind overhead. Wssshhhhhh, Wshhhhhhhhh, it whistled. She smelled the grasses of the new nest, her parents, and her littermates. And, very faintly, she smelled that terrible odor that she had noticed in the old nest. Di now knew that the awful smell meant danger. For now, though she was safe in the new nest with her parents.

Di and her littermates grew larger over the next few days. Soon there was not enough milk to feed all the growing young. Di soon felt hungry and the nest felt too crowded. So she left the nest. It was colder outside, but Di stayed warm because by now she had grown long fur. She slowly walked down the snow tunnel away from the nest. She looked, listened, and smelled all the new things she found. Soon she smelled something that made her remember she was hungry. She dug through the snow without thinking. Two shovel-like claws on her front paws helped Di scrape and dig through the hard snow. She found a small willow plant. Di filled her stomach with the twigs and buds of this plant. Then she began exploring again.

Di scurried from one tunnel to another for the next several weeks. She slept in nests that she found along the way. She ate whatever smelled good. Di could not find very much to eat. So she had to move further and further away from the place where she was born.

One day she found a tunnel that ended above the snow. Di cautiously peeked out into the open air. Ice crystals blown by a strong wind blasted into her face. The wind bit the tip of her nose and her breath turned to white fog. Di was still curious. She poked her head out further and saw a small hill. The hill was only 2 feet tall but to Di it looked very large. She scampered up it to find out what was on top. She found a patch of ground without any snow. The frozen soil was bare and brown. Di saw only a few small plants. The dead leaves and stems of these 2 inch tall plants spread over the ground like mats. Di ate a few buds that she found hidden under these dead leaves. Then she looked around. Flat, snow-covered ground stretched out as far as she could see. There were no trees or mountains to block the view. The sun was just above the southern horizon. It lit the sky with a reddish light.

Just then Di heard a noise. Crunch, crunch! Di dove back into her snow tunnel. Then she turned around and looked out carefully. She saw six giant beasts moving towards her. The crusty snow squeaked and snapped beneath their feet as they walked. Their short legs were almost hidden by long, wooly fur. Each one had horns that looped down either side of their shaggy faces. They stopped to paw the ground as they moved nearer to Di. They nibbled at some plants, then stopped to chew. The muskoxen did not seem to notice the bitter cold and wind. But Di suddenly felt cold. She turned and ran back down her tunnel to a warmer spot beneath a large drift of snow.

Di dug her own tunnels to find food during the next few months. She learned that it was warm beneath soft, deep snow and cold under the crusty snow. She also found many new things. One day she found a beetle that was frozen. Another day she found frozen berries. She ate these. She also nibbled on the frozen buds of willow and gnawed on the stems of grasses.

Di soon learned to recognize the sounds of other animals. She knew the sounds that other lemmings made as they gnawed on twigs. She knew the sound of muskoxen crunching through the snow. And she also learned to recognize the sniffing and pat, pit, pat of a hunting arctic fox. Di knew she must fear this sound. So whenever she heard it, she sat very, very still.

Each day in the snow tunnels was just like the last. Di dug tunnels through the snow. She looked for food and found it. She listened to the sounds around her and always hid when she heard a fox. The arctic tundra provided Di with food, shelter, and places to hide from her predators. She could not have had a better home.

CHAPTER 2. SPRING--CHANGES IN THE AIR

Di often dug tunnels to the surface of the snow just to see the world above the snow. Once when she dug a tunnel to the surface she saw another tunnel in the snow just a few feet away. She saw nothing around except white snow, so Di decided to have a closer look at it. She noticed that the sky was brightly lit out in the open. The wind was still and the air seemed warmer than ever before. Di began to explore the white world around her. She looked, listened, and sat on her haunches to sniff the cold air. But she did not see the large white bird that sailed quietly over the snow toward her. Its large black claws stretched out toward her back. Suddenly, Di rushed into the nearest tunnel--she barely noticed the owl's shadow in time. This time the snowy owl would have to search for a some other lemming to eat for its dinner.

Di's tunnels through shallow snow were light almost all of the time now. They had been dark all the time when she had first begun living on her own. Now it was almost too bright to see outside as the snow glistened and flashed in the sunlight. Di, curious as ever, still regularly visited the snow surface. But after her encounter with the snowy owl, she was much more careful.

One day, as she contently gnawed on a willow branch, Dicrostonyx heard a new sound. It was a beautiful, melodic whistle. She hurried up to the surface to see what was making the pretty sound. The wind was howling outside the tunnel. It was hard to see through the blowing snow. When she heard the beautiful sound again, Di spotted the singer. It was a small bird with striking black and white feathers and a small cone-shaped bill. The snow bunting was perched on top of a small snowbank near the entrance to one of Di's tunnels.

After that day, Di noticed many changes in her world. The snow changed to ice in some places. Di could not dig through the ice. In other places, the ends of Di's tunnels simply disappeared. The tunnels in deep snow that were once warm, became wet and icy. Some filled up with water. Di got very cold when her fur got wet. So she began to avoid the tunnels in the deep snow and started spending more time on top of the snow. Her fur was brown, so she was camouflaged when she hid amongst the brown leaves of the tundra plants. None of the plants were more than a few inches tall. Di had to be very still when she wanted to hide.

This was a dangerous place and time for a lemming. Di saw, heard, or smelled an arctic fox almost once every week. Twice she smelled the horrid odor that she remembered from her days with her mother. Once she saw an owl carry off a lemming that had been too careless. These events made Di wary. She sniffed the air often. She always looked carefully before going above the snow. She moved slowly. And she listened, even for faint noises.

Cack, cack, cack, get-back, tobaggo, tobaggo! Di jumped nearly 3 inches off the ground when that loud cackling call exploded behind her. She raced under a tussock of grass and sat with her heart pounding. Tobaggo, tobaggo, tobaggo! Di carefully peeked out of her hiding place. She saw a ptarmigan eating willow buds. It had a brown head, a white body, and bright red combs over its eyes. Tobaggo, Tobaggo, Tobaggo! it called.

Di saw a new bird every day. Most were flying to other places. They came, and left, in great flocks. Often she heard large flocks of birds flying over. Their wings whistled in the wind. And most of them called out. Honk Honk! Honk! Quack...quaaack, quaack. Phsss, phss, phss. She heard the sounds during the sunlit day and in the short twilight of night. Perhaps Di did not know it, but spring arrived with the birds.

CHAPTER 3. SUMMER--A DIFFERENT WORLD

The weather often changed as spring turned into summer. One day was warm and the snow melted. Then snow fell and the winds howled the next day. Soon, however, Di could not find snow to tunnel through. She had to swim in places where she had once run through snow. She found flattened piles of wet grass in places where she once had built warm nests. Di, like all the lemmings, was forced to move to high spots on the tundra. Water covered everything else. Di could not find many places to hide, because few plants grew on the dry spots of tundra. Usually she hid under the dry leaves of a grass tussock.

Soon, the song of the snow bunting and outbursts of ptarmigan were hard to hear because the air was filled with the calls and songs of many kinds of birds. Lapland longspurs flew high into the air to sing songs that sounded like ice tinkling in a crystal glass. Boom, boom, boom, the drum-like calls of into the air then dove toward the earth. "Psssssssssssssssh!" they whistled. "Ah ha leeek, ah ha leek" the calls of oldsquaw ducks rose from every lake and pond. But even these were drown out by the loud, haunting cries of loons: Hulawhoooo, Hulawhoooooo.

The birds began nesting almost as soon as they arrived. Loons, geese, and eiders nested on the tiny islands in the midst of frozen tundra lakes. Sandpipers nested in the bare spots between patches of melting snow. The tundra was blanketed with snow when another snow storm passed through. The nests, eggs, and incubating birds were soon covered by wet snow. The birds could do nothing but wait for the snowstorm to stop. If they moved off of their nests, their eggs would get too cold.

Di waited for the snow storm to end too. The snow was too wet to tunnel through, so she hid under a grass tussock. When she felt the ground shaking, she poked her head out to look for muskoxen. But she saw something else. The long-legged animals trotting toward her were thinner than the muskoxen. They had short fur and thin antlers. They moved quickly, barely stopping to munch on the grasses and sedges. Di saw 20 caribou that came close to her. Nearby, tens of thousands wandered over the tundra.

Di had much on her mind during these days of early summer. She had to dodge the hooves of the caribou. Jaegers, a new kind of bird predator, had appeared with the great hordes of other birds. Di had to be very careful to keep hidden from them, and from owls. She listened for foxes and often sniffed the air for the smell of that unknown danger.

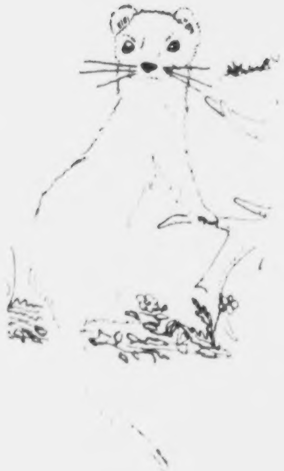
But Di found many new things to eat. She found green leaves and beautiful flowers on plants that had seemed dead during winter. The tundra was dotted with yellow, white, blue, and purple flowers. As Di feasted on this new variety of food, she grew large.

Many tundra animals, like the birds, were soon busy raising young. Within 2 weeks after the caribou arrived, almost every cow gave birth to a calf. The muskoxen had their calves in the willows down by the river. Every day arctic foxes trotted across the tundra to carry lemmings, birds, eggs, and other prey to the 4 young in their underground den.

Soon Di found a mate, and like the other tundra animals, began raising young. She and her mate dug a tunnel into the dry soil on the edge of a small rise in the tundra. Di discovered that just a few inches underground, the soil was still frozen solid. Di could not have found any warmer place to build her nest. The frozen earth she found, called permafrost, underlies nearly all of the lowland tundra in Alaska, so she could not have found a warmer place to nest. She built a warm nest of grasses, muskox fur, and ptarmigan feathers to help keep her young warm in the cold burrow.

As the days grew warmer, many kinds of insects began to appear. Bumblebees in yellow and black fur coats hatched from eggs that had been buried in the soil. They soon buzzed from one flower to the next. Yellow, blue, orange, white, and even black butterflies and moths came out of the chrysalis' and cocoons in which, as larvae, they had slept through winter. Flies and mosquitos hatched from the eggs that had survived winter. They soon filled the air with a constant hum: Bzzzzzzz Bzzzzzzzz Bzzzz. Every warm-blooded creature from caribou to lemming, goose to longspur, soon knew the annoying sounds and bites of the mosquito hordes. Caribou often ran wildly across the tundra to try to escape these and other insects.

The summer season passed quickly. One day, the caribou herd headed inland on another part of their endless migration. The eggs in hidden shorebird nests turned into long-legged, downy chicks. Soon after hatching, these chicks hurried after their parents in search of insects to eat. Broods of ducklings followed their mothers around the edges



On one of her visits to the surface she saw a strange white animal that she had never seen before. Its long body, short legs, and long tail tipped in black gave it an odd look. It moved by bringing its hind legs up near its front ones, then moving its front legs out. It looked a little like a very large and very fast caterpillar. Always cautious, Di watched it carefully and sniffed the air. The animal was downwind of her so she could not smell it. But she noticed that it was also sniffing the air and it seemed to be moving right towards her. She backed further into her snow tunnel, but continued watching.

It was coming towards her even more quickly now. Something about its approach reminded Di of a hunting fox, so she decided to run away. She slipped down her snow tunnel away from the animal. Then she took a side tunnel that would lead to a spot downwind of the animal. Perhaps if she could sniff its scent, she would know what it was.

Di stopped and sniffed as she neared the end of the downwind tunnel. She nearly froze in terror when she smelled the strong odor of the danger she had known since her earliest days. She knew she must hide. But she had not had time to dig many tunnels in the snow. She peeked out the tunnel she was in and saw the tip of the weasel's tail disappearing down the entrance to the tunnel she had just been in. The animal's long narrow shape was just right for traveling in lemming tunnels. Di suddenly knew that the weasel was hunting her. If she ran back down her tunnel she would run right into it.

Di decided to run over the snow surface instead. Scampering across the snow, she ran one way, then the other. The wind had formed a crust on the snow so it was easy to run across it. Di did not look back to see if the weasel was following. She just kept running as fast as she could. The winds had blown the snow into drifts. Di had to run up and down, up and down over these. In her rush Di did not see the drop-off near the edge of a frozen lake. She tumbled head over heels down the drop-off. Down, down, down she went. When she finally landed in a snow bank. She lay stunned for an instant. Then she dove into the snowbank. She dug as fast as she could and kicked snow to fill the tunnel behind her. At last she was too tired to dig further, so she stopped. Her heart was racing so fast she could hardly hear. But she listened carefully and sniffed the air. She heard nothing and could not smell anything. Still she lay quietly. She did not want to make any noise that would help the weasel find her. She soon fell asleep.

Di started when she awoke. She calmed down only after sniffing the air. It smelled fresh and clean. Di had escaped the weasel. Now it was time to find food. Di dug tunnels through the snow of this new area. When she finally had time to peek above ground, she felt the icy blast of winter winds and the freezing chill of below zero temperatures. She could see only darkness. Winter was a silent season. The wind howled. The ice groaned. Sometimes the sound of Di's teeth gnawing on willow twigs echoed through her tunnels. Di lived in her snow tunnels during these months of wind, snow, and darkness. The northern lights lit the dark sky over the tundra in February. Di cared for another litter of young under the snow. They would begin their lives, as she had, in the darkness of a warm grass nest beneath a blanket of snow.

Permafrost Puzzles...............SCIENCE...........INDOORS/OUTDOORS

OBJECTIVES:Students will become aware of the effects of permafrost on the soil surface and landscape by simulating permafrost in a pan, acting out the formation of ice, and freezing water.
MATERIALS: 2 cake pans, a glass or plastic container with a tight lid, freezer, soil, water.
PROCEDURE:
1.PREPARATION: Fill 1 cake pan with at least 2 inches of moist soil, then freeze it. Fill another cake pan half full of moist soil, but do not freeze.
3. DISCUSS THE TERM PERMAFROST: Ask students what is meant by the term permafrost. If they do not know, explain that this is a term used to describe soil that is frozen year-round. Ask whether this occurs in the area of your school.

If students don't know the answer, this is a good opportunity to find out. In the fall, you can find out by driving a rod into the ground as far as possible, or digging a hole until you hit ice. If you are doing the lesson in late spring, the ground may still be frozen even in areas that do not have permafrost. Discuss with students when they think the ice in the ground melts. Check the depth of the ice weekly until school is out and encourage students to continue checking throughout the summer to find out whether or not permafrost occurs in your area. Alternatively, have students check a copy of the Environmental Atlas of Alaska (see the reference list) and find out if permafrost occurs in your area.

After students understand what permafrost is, ask them how they think permafrost soil might be different from unfrozen soil. Encourage them to make some predictions, or hypotheses, by asking questions--would it be warmer or colder? harder or softer? Would it soak up more or less water? Would it take up more or less room?
4. TEST STUDENT PREDICTIONS: Retrieve the pan of soil from the freezer and have students test their predictions. Have a student try to stick a fork in the soil to find out if it is harder or softer. Ask students how the hardness and temperature might affect plant growth. Have students pour a tablespoon of water on the two pans of soil. What happens? Which one soaks up the water?
5. DEMONSTRATE THE EFFECTS OF FREEZING WATER: Completely fill a glass or plastic container (with a lid) with water. Ask students what they think will happen when you place it in the freezer. Conduct an experiment to find out. Can students explain why the container broke? Help them recognize that water expands (gets larger) when it freezes. So there was not enough room in the closed container to hold the frozen water and it pushed out. Have students pretend they are water and act out the process of freezing. Have all the students stand in a circle. Draw a circle around them, so that all students are inside it. Explain that they each represent a water molecule. While liquid, the water molecules can "stand" side by side, but when water freezes, it forms ice crystals. Ask students to form ice crystals--each "molecule" must spread their arms straight out to the sides. They must touch the fingertips of another "molecule," but no other part. What happens? (They have to spread out and they don't fit in the circle.)
6. USE THE PERMAFROST INFORMATION PROVIDED IN THE TUNDRA WILDLIFE CARD SUPPLEMENT TO SHOW THE TOPOGRAPHIC FEATURES OF PERMAFROST SOILS. Have students make clay or play dough replicas of each of the features.

A walk across the tundra...........
Language Arts....Indoors/Outdoors

OBJECTIVES: Students will demonstrate their awareness of the tundra environment by making up and acting out a play about the tundra.
MATERIALS: none.
PROCEDURE:
1. Divide the class into small groups. Assign each group one of the seasons and ask them to make up a short play about walking across the tundra in that season. Encourage them to think about the wind, the cold, what the ground would be like, and what animals and plants they might encounter. One student can act the person in the play, while the other students might act out various animals or plants. Students may make any kinds of sound effects they want to, but are not allowed to use words. Allow about 15 minutes for them to figure out their play.
2. STUDENTS PRESENT THEIR PLAYS. Have students present their play to the rest of the class or other classes. Ask the other students to guess what season the players are acting out.

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BRRR..COLD!...................SCIENCE..............INDOORS

OBJECTIVES: Students will gain a better understanding of cold and the ways that it affects the world around them.
MATERIALS: water, soil, pans, light bulb, ice, bean plants (in small pots), fresh apple slices (or moist bread), several margarine or other opaque plastic containers.
PROCEDURE:
1. STUDENTS DISCUSS THE TERMS WARM AND COLD. Students have learned that tundra is a cold environment, but what does that mean? Why is this important? Ask students what we mean by saying cold. (There is little heat present.) Discuss methods of measuring the amount of heat present. Examples include by touch, thermometers, or by observing--for example, whether or not water is frozen. [If students become curious about what heat is, you may want to explore ways of producing heat--i.e. fire, friction, light, exercise, and eating food. Heat is a form of energy, and energy is released by all of the above.]
2. STUDENTS FORM HYPOTHESES ABOUT THE EFFECTS OF COLD. Ask students how cold affects various things--water, rocks, plastic, soil, animals, and plants. It's likely they won't know--so this offers a good chance for them to think of experiments to find out . Here are a few suggested experiments:
1. Go outside on warm and cold days and try to observe how things are different. Keep lists of things students observe on each of the days. Encourage them to listen to the sounds of their feet, feel the texture of the snow, the brittleness of plant leaves, the hardness of the ground, and to look for the presence of ice or liquid water, and for animal activity. Encourage them to look closely at any animals they see (e.g. are bird's feathers puffed out when it's warm or cold? Are dogs curled up with their tails over their noses, or are they active?) How do student's hands work in the cold? Do they get stiff? Why?

2. SOLID, LIQUID, GAS. Try exposing various things (including water, margarine, juice, and plastic) to heat and very cold temperatures. These experiments can lead into discussions of molecules and the three states of matter--solid, liquid, and gas. This can best be illustrated with water, but students may be excited to find that other things have liquid, solid, and gas forms too. (Margarine is a good example of something with a warmer "freezing" point than water; most juices have lower freezing points than water.)

3. PLANT GROWTH: Try growing bean plants under different temperature situations. Keep the plant pots, soil, light, and water schedules the same for several small bean plants. But keep some of the pots in a pan containing ice, others at room temperature, and place a light bulb underneath a pan containing the others (to create a warmer environment). Which plants grow the fastest? Why?

4. DECOMPOSITION: Ask students what would happen to a section of apple placed inside a sealed plastic container. Stimulate their thinking by suggesting that surely nothing could get into the sealed container, so probably nothing would happen....right? Then, find out. Put a slice of moist apple in each of 2 (or more) sealed containers. Put each of the containers in a different environment (in a cold place, in a cool place, in a warm place, and in a hot place.) Have students re-examine the contents once each week and record the changes. Have them try to figure out what happened. Can they figure out that microscopic organisms are present in the air and on the food. How did cold affect the process of decay? Why was the decay slower in the cold container? (Because the bacteria and fungi that decay things can't grow as fast in a cold environment.)

Alaska Wildlife Week 1988: The Living Tundra © 1988 ADF&G

TUNDRA AROUND THE WORLD
SOCIAL STUDIES, SCIENCE....INDOORS

OBJECTIVES: Students will become familiar with the distribution of tundra environments around the world.
SKILLS: map reading and use of a globe, drawing conclusions
MATERIALS: A globe showing the mountain ranges on earth, saran wrap, marking pens that write on plastic, and a map showing the distribution of tundra on earth (see following page)
PROCEDURE:
1. PREPARATION: Wrap saran wrap around a globe so that students will be able to see the globe, but can also mark on it without harming it.
2. DISCUSS THE OCCURRENCE OF TUNDRA: Ask students where on the earth they think that Dicrostonyx the lemming might live. Do they think a similar type of environment might be found anywhere else on earth? Ask them how they could find out. (You may want to discuss a bit of history about the exploration of the earth, and how amazing it is that we can find out where tundra occurs today just by looking at maps made by other people and by the use of satellites. Then show students the map and help them figure out some of the places on earth where tundra occurs.)
2. Assign individual students to transfer the information on the map onto the world globe so that they can better visualize the distribution of tundra on the earth. Ask them to look carefully at the places on the globe where tundra occurs. Does it occur in the ocean? On land? Near the equator? Near the north pole? Near the south pole? On the coasts? In the mountains? Help them discover that tundra occurs on mountaintops around the world, and at high northern and southern latitudes. (Note that there is little at southern latitudes because there is little land at the appropriate latitudes.)
3. Discuss why it might be that tundra is found in these two places. (Students may know it is cold in the north and on mountaintops. If not, help them use the encyclopedia to find out that it is hot near the equator, cold near the poles, and cold on mountaintops. They should recognize that tundra occurs where it is cold.)

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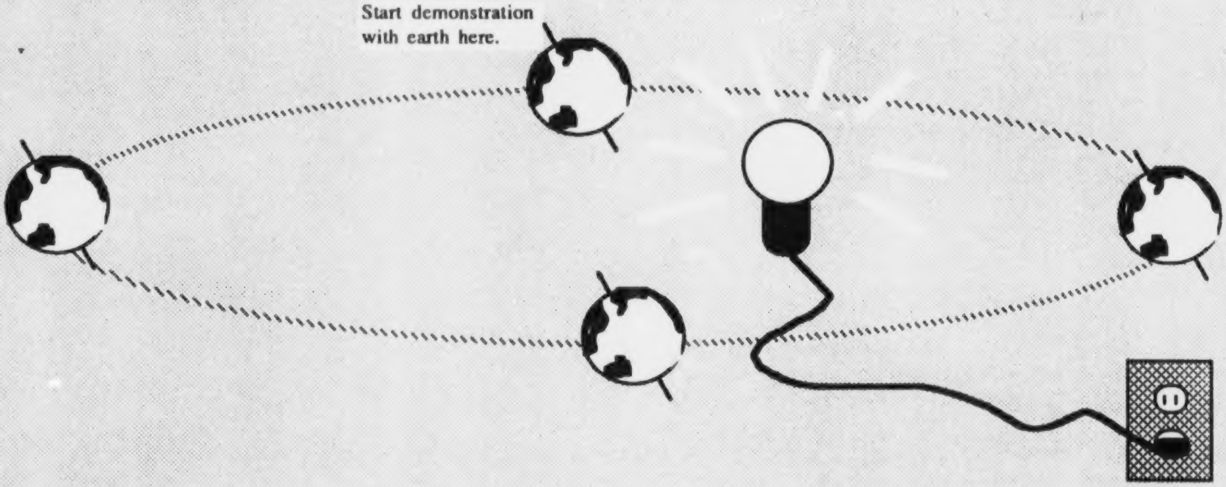
Understanding the North..Science
....Indoors



OBJECTIVES: Students will understand why the winters are cold and dark in the arctic.
MATERIALS: bright lamp, globe or styrofoam ball with pencil or wire.
PROCEDURE:
1. PREPARATION: Use a globe, or sketch the major continents on the styrofoam ball along with the equator and 66°33'N and S latitudes (the arctic and antarctic circles). Insert the pencil or wire through the center of the styrofoam ball. Set the light up on a small table so that you or a student can walk around it.
2. FAMILIARIZE STUDENTS WITH THE MODEL: Explain to students that the lamp represents the sun, and the globe or styrofoam ball represents earth. Show the the location of the north and south poles (the pencil in the styrofoam ball). Have students find Alaska on this model of earth. Next, show the tilt of the earth on its axis (23 1/2°) and demonstrate the earth's location relative to the sun. To begin with hold the earth in the equinox position--i.e. so that the axis of the earth is pointing along its revolution path rather than pointing into or away from it--see diagram. Ask students to examine the pattern of light and dark on the "earth". Demonstrate how the earth rotates, resulting in night and day.
3. DEMONSTRATE THE REVOLUTION OF THE EARTH AROUND THE SUN: Keep the axis of the earth pointed in the same direction and have students watch how the light and dark portions of the "earth" change as it moves around the "sun". Explain that the earth makes one revolution (circle) around the sun each year. Have students decide when it is summer in Alaska, and when it is winter. Can students figure out why it is cold and dark in the winter in Alaska? Ask them if it would be cold in the southern part of the globe when it is winter in Alaska. Is it ever winter at the equator? Use the model, along with questioning to help students see and understand why there are dark, cold seasons in the north and south, but not near the equator.
4. RELATE THE OCCURENCE OF COLD, DARK WINTERS TO THE OCCURENCE OF TUNDRA: If students have not previously learned where tundra occurs on earth, explain to them, that most of the tundra occurs in northern lands, above the arctic circle. See if they can figure out, by looking at a globe, why there isn't more tundra in the southern hemisphere. (Cold, dark winters occur in the north and south, but there is little land at high southern latitudes.)

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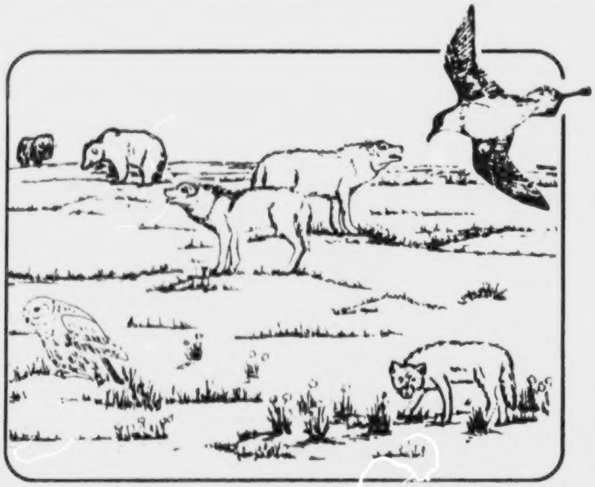
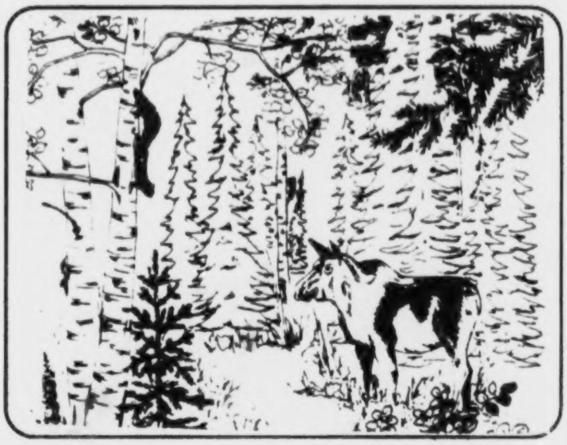
Primary

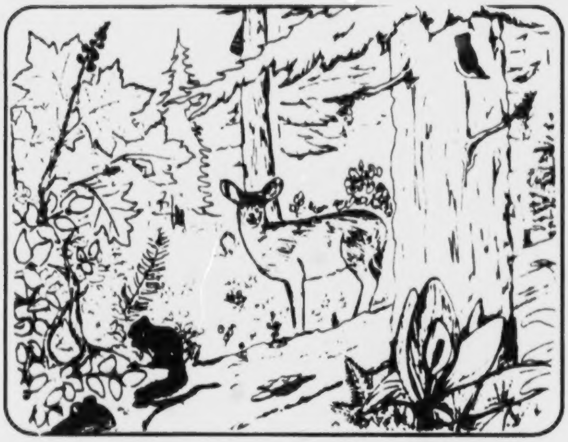
Worksheet 1.
Tundra Scenes

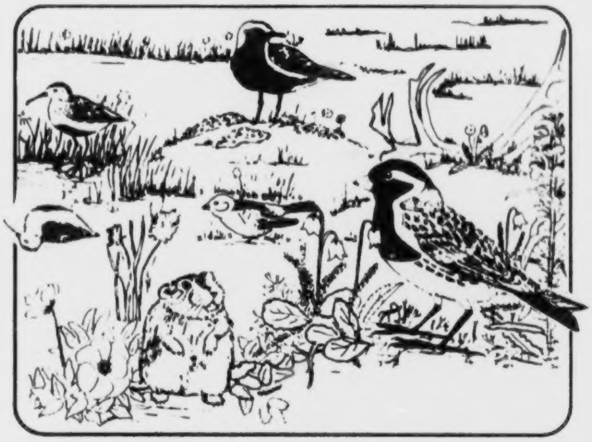
Name____

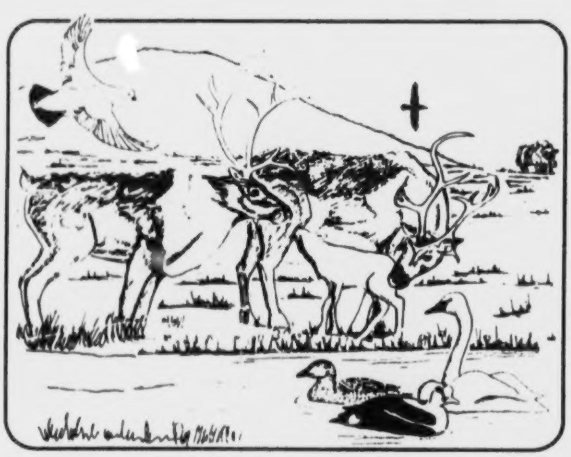
Draw a line under all the pictures that show a tundra environment.

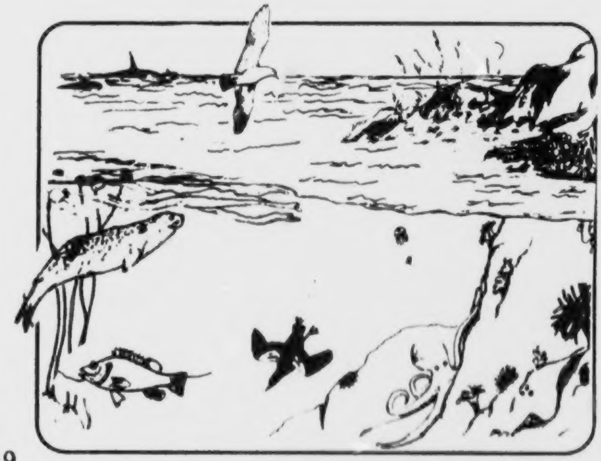












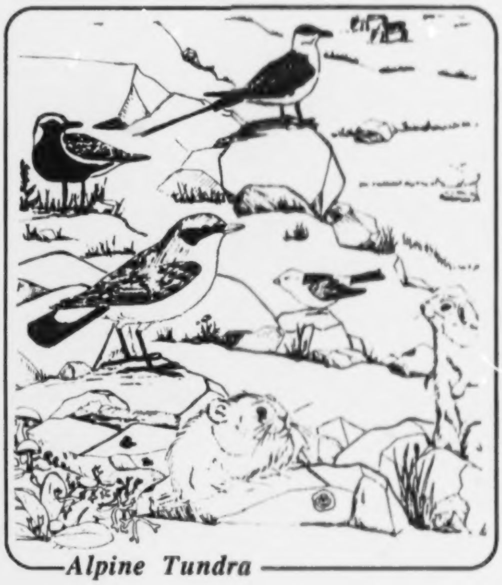
Alaska Wildlife Week Unit 6. Tundra. © 1988 ADF&G

Lesson 2.

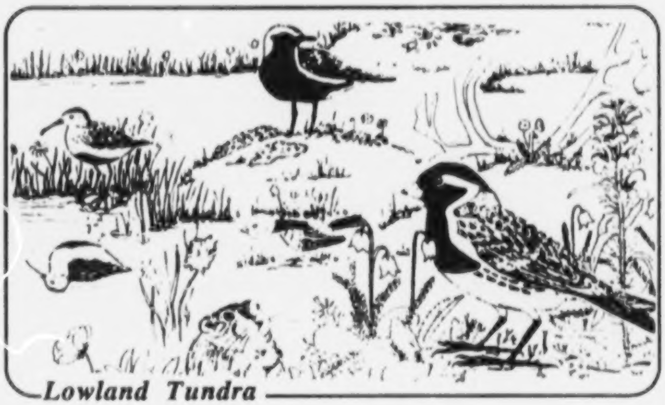
Primary

Vocabulary

alpine tundra, animals, fungi, lowland tundra, monerans, plants, protists, wetland



Alpine Tundra



Lowland Tundra

Objectives:

Students will be able to differentiate alpine and lowland tundra and describe some of the features and living things characteristic of each.

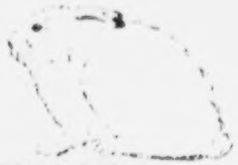
Teacher Background

IS ALL TUNDRA THE SAME?

Nearly half of the land in Alaska is tundra, but not all tundra is alike. The term "tundra" is used to describe all ecosystems that share the characteristics of periodic severe cold, short growing seasons, persistent winds, and the absence of trees. These characteristics make all tundra ecosystems look superficially similar, but the non-living environments and the species of living things present vary between regions and specific areas. The two main types of tundra ecosystems that occur in Alaska are alpine and lowland tundra, but even within these categories tundra ecosystems vary from one region to another.

HOW DO ALPINE AND LOWLAND TUNDRA ENVIRONMENTS DIFFER?

- Alpine tundra occurs at high elevations (mainly on mountains) throughout the world, while lowland tundra occurs at low elevations in polar regions, coastal subarctic areas, and on subantarctic islands. In Alaska, lowland tundra occurs north of the Brooks Range, in northwestern and western Alaska. (The treeless environment in parts of coastal southwestern Alaska and the Aleutian Islands is also sometimes classified as lowland tundra, but it is warmer and moister than typical lowland tundra, and is sometimes classified as grassland.) Alpine tundra occurs on mountains throughout the state; it grades into lowland tundra in northern and western Alaska.
- Alpine tundra is a discontinuous habitat. It occurs in patches separated by the forests and wetlands of lower elevations, and the ice and snow of high elevations. Many alpine sites are like islands of tundra. In contrast, lowland tundra covers vast, continuous expanses of land, such as the North Slope and the Yukon Kuskokwim River Delta.
- The topography of alpine and lowland tundra differs greatly. Alpine tundra sites are characterized by abrupt changes in slope and aspect; flat and gently sloping areas are intermixed with steep slopes and cliffs. The underlying terrain of lowland tundra, in contrast, is generally flat, or gently sloping. However, wind, water, and permafrost continually shape and carve the surface of lowland tundra. In lowland tundra areas underlain by permafrost, topographical relief occurs, including thermokarst ponds, ice wedge troughs, thaw lakes, high and low-center polygons, and pingos,



ice-filled hills that can rise 164 feet (50m) above their surroundings, . (See the illustrations and descriptions of these features in the Tundra Wildlife Cards Supplement to this packet.)

- Daily temperature fluctuations are more extreme in alpine than in lowland tundra. The air at high elevations is less dense than the air at lower elevations. As a result, alpine tundra receives more intense solar radiation (less is filtered by the atmosphere) during the day, and cools more quickly at night. Freezing temperatures may occur at night year-round in alpine tundra. Long cold winters occur in both alpine and lowland tundra, but a 2-month period of darkness with little or no sunlight occurs only in tundra at high latitudes (mainly lowland).
- Most alpine areas receive more snowfall, and thus more precipitation, than lowland tundra. Alpine areas in northern Alaska receive about 20 inches (51 cm) of precipitation per year, but alpine tundra regions in southcoastal Alaska receive 100-200 inches (250-500 cm) or more. (In some southcoastal Alaska mountains, scientists have recorded as much as 18.75 feet (5.7 m) of snow in a single month!) In contrast, most lowland tundra receives only 4-20 inches (10-51 cm) of precipitation per year. This level of precipitation is comparable to that of deserts and arid grasslands.
- Contrarily, most alpine tundra is dry, while most lowland tundra is wet or moist. High winds, dry air, intense solar radiation, shallow soils, and good drainage due to the mountainous topography result in dry condtions in most alpine tundra, despite heavy snowfalls. However, some alpine sites have adequate or abundant water; snowbanks that melt slowly provide a continuous supply of water to sites below them, and water collects in depressions and flat areas of alpine tundra.

In striking contrast to the dry, rocky land of alpine tundra, most of Alaska's lowland tundra is wet or soggy during summer. This occurs because nearly all lowland tundra is flat or gently sloping, and is underlain by permafrost (perennially frozen soil). Water cannot seep through permafrost, and flows slowly over flat ground, so all of the water from rain and snowmelt remains on the surface in lowland tundra. Evaporation and transpiration (the release of water vapor into the air by plants) occur slowly due to the cool temperatures. Thus, many lowland tundra areas remain wet during the entire summer.

- Shallow soil, rock piles, rock outcroppings, and cliffs are important features of alpine tundra, though deep soil occurs in gently sloping areas. In contrast, most lowland tundra sites have deep soil and rock outcroppings are uncommon except in the high arctic.

The exposure of bare rocks in alpine areas results from soil erosion caused by landslides, avalanches, high winds, fast-running meltwater, solifluction (sliding of the active layer of soil atop the permafrost layer on sloping land), and frost-heaving.

Little erosion occurs on the relatively flat terrain of lowland tundra; most dead organic matter remains in place or is washed into lakes and ponds. Centuries of accumulation have resulted in deep layers of partially decayed material, or peat. Many lowland tundra areas are also periodically flooded by slow-moving rivers that deposit silt and organic material from upriver.

- Environmental conditions in alpine and lowland tundra vary considerably depending on latitude, elevation, aspect, and slope. Both types of tundra gradually change from very dry, cold environments with lots of bare soil and rocks, to zones where most of the ground is covered by lichens and mosses, and finally to a warmer, moister zone dominated by low shrubs. In alpine tundra, this variation occurs mainly over an altitudinal gradient, from high to lower elevations. Variation in lowland tundra occurs mainly along a latitudinal gradient from northern, arctic regions to more southern, coastal subarctic regions.

WHAT LIVING THINGS OCCUR IN ALASKA'S TUNDRA ENVIRONMENTS?

Considering the severe conditions of tundra environments, it seems surprising that any living things can survive in the tundra regions of the earth. In fact, some people mistakenly assume that tundra is barren and desolate wasteland. However, representatives of all five kingdoms of living things occur in tundra environments. Though generally fewer species occur than in milder environments, many of the species present occur in astonishing abundance. Many of the species of plants, animals, and other living things found in tundra do not live in other environments.

The numbers and variety of living things present decreases as the severity of the climate increases; thus fewer species of living things are found on the tundra in the far north than in the subarctic maritime tundra, and, in alpine tundra, more species are found near treeline than at higher elevations. Some kinds of living things occur in both alpine and lowland tundra. But, many alpine tundra wildlife require well-drained, dry, rocky, or precipitous sites that are not available in lowland tundra, while many wildlife of lowland tundra are aquatic or semi-aquatic and could not live in dry alpine tundra.

General information about the living things found in Alaska's tundra ecosystems is provided in the introduction to the Tundra Wildlife Cards that go with this packet. Also, see the three posters that accompany this packet for illustrations and photographs of many tundra wildlife.

Introductory Activity 2.

Objective:

Students will become familiar with the variety of living and non-living things found in alpine and lowland tundra environments.

Skills:

SCIENCE: observing, comparing, classifying.
LANGUAGE ARTS: oral communication skills.

Materials:

Posters of alpine and lowland tundra and tundra wildlife cards, both in this packet

Procedure:

SUMMARY: Students will compare the drawings and photos of alpine and lowland tundra and try to identify similarities and differences in the environments and living things present.

1. INTRODUCE THE POSTERS: Show the illustration of lowland tundra and ask students to name the environment it shows. Remind students of the story about Dicrostonyx and the place she lived, if they don't immediately recognize the tundra. Explain that there are two kinds of tundra found in Alaska and in the rest of the world. These are lowland tundra, the kind described in the story, and alpine tundra, shown in the other illustration. (Bring out the poster of alpine tundra.)

2. STUDENTS COMPARE THE TWO POSTERS: Ask students to look carefully at the two posters and name any similarities they can see between the two tundra environments. (Have students raise their hands and explain to the class any similarities they see; or call on students individually.) How are the two environments alike? Use questions to help students notice some of the similarities. Do both environments have sunlight? air? water? dirt and rocks? Do they both include animals? plants? Are any plants and animals the same? Do the places look similar to each other? How? Are any kinds of plants missing from both environments? (trees) List the similarities on the board.

Praise students for finding these similarities and explain that the non-living environments of the two types of tundra are similar in many ways. Both alpine and lowland tundra have long, very cold winters. This causes some of the similarities in the two environments--for example the absence of trees.

3. STUDENTS LOOK FOR DIFFERENCES IN THE TWO ENVIRONMENTS: Next, explain that although alpine and lowland tundra are similar, there are also some differences between them. Ask students to try to find some of the differences. Have students raise their hands and explain any differences they observe, or call on individual students. Again, encourage them by asking questions. Is the ground the same in both environments? How does it differ? (More rocks, slopes, and cliffs are present in alpine tundra.) Is there more water in one environment than in the other? Are the animals and plants the same? (Some are, some are not.) List the differences on the board.

4. STUDENTS IDENTIFY THE LIVING THINGS IN THE TWO TUNDRA TYPES: Students may recognize some of the living things pictured in the two environments, but they are likely not to recognize many. As a challenge to students, allow them to look at the posters over the next few days, and in their spare time make up a list of all the animals, plants, and fungi shown in each poster. Explain that students can find out the names of the animals and plants they don't recognize by comparing the pictures to those on the Tundra Wildlife Cards, or to pictures in other books about Alaskan wildlife. Ask students to be prepared to point out each of the living things they list, and if possible to tell something about the creature.

5. STUDENTS COMPARE LISTS: As a class activity, review the lists for each poster. Ask students how many animals, plants, and fungi they found pictured on each poster. Call on each student to point out and identify 1-2 living things on each poster until all those shown are identified. (Make a master list for each poster on the board.) Then compare the lists. Which animals were found only in alpine tundra? (Marmots, pikas, mountain goats, Dall sheep, water pipits, and horned larks). Which were found only in lowland tundra? (Loons, geese, eiders, phalaropes.) Question students as to why these differences occur. Encourage students to think about where the animals live and whether or not the necessary habitat is found in both types of tundra. (Rocky slopes and cliffs needed by these alpine animals are not found in lowland tundra, and the ponds and wetlands needed by geese, ducks, loons, etc., are not found in alpine tundra.)

Evaluation:

Students complete Worksheets 2a, 2b, and 2c.

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TUNDRA WILDLIFE WATCHERS.
................Language Arts, Science
.......................Indoors/Outdoors

OBJECTIVES: Students will become more familiar with living things characteristic of Alaskan tundra by playing a game that requires them to recognize and learn the names of many.
MATERIALS: Tundra Wildlife Cards, spinner, pencil and paper
SKILLS: Observation, communication, memory
PROCEDURE:
1. STUDENTS REVIEW WILDLIFE CARDS: Have students sit in a circle on the floor. (If you have a large class, you may want to divide it into 2 or more small groups.) Hand out one Tundra Wildlife Card to each student. Go around the circle and have each student tell the name of their animal (or other living thing), and (optional) something interesting about it. Then ask all the students to look at everyone elses' cards very carefully, so that they can remember all the animals present.
2. PLAY WILDLIFE WATCHER: Use the spinner to determine who is "It." Ask that all players close their eyes. Then, give one student a new wildlife card. Then have all players open their eyes and have the "It" player try to find the new animal. If he/she can point to it, he/she gets one point. (The player holding the new card tells the name of the new living thing if the others do not know it.) If the "It" player can then name the animal that was removed from the game, he/she gets another point. Play then moves to the right. Again, change one card, and the next player tries to guess which living thing is new, and which one, present previously, is now missing. Play long enough that each player gets at least 2 chances. (Hints are allowed.)
3. REVIEW THE LIVING THINGS FOUND IN TUNDRA: Give each student a piece of paper and a pencil. Allow 5-10 minutes to see who can make the longest list of living things found in tundra. Each player gets one point for each creature listed, but loses 2 points for anything listed that does not occur in tundra. Add the points gained here to those earned in the game to find the champion Tundra Wildlife Watcher.

Pika Tag..................................SCIENCE, PHYSICAL EDUCATION
....INDOORS/OUTDOORS

OBJECTIVES: Students will become more familiar with a tundra animal, the pika, while playing an active game.
MATERIALS: large playing area, different color vests or tags to identify pikas, 1 hawk, and 1 weasel, cards or other markers to represent food, a timer
PROCEDURE:
1.BACKGROUND: Show studentsa picture of a pika (from poster). Explain that pikas are small animals related to hares and rabbits. They live in rock scree slopes of alpine tundra. Pikas must gather food every summer and dry it in the sun to have enough food to live through winter. They have several predators, but the most important ones are hawks and weasels. Pikas have an interesting habit--they call out "Myaaaa!" (like a goat bleat) whenever they see a hawk, but they are quiet if they see a weasel. Explain that the class is going to play Pika Tag--a game about the pika and its predators. Have 15-20 students join hands and form a large circle. Then draw a line to show a small inner circle (3-5 feet in diameter). Select 2 students to represent predators; the remainder will be pikas. Scatter food cards inside the perimeter of the outer circle. Then explain the rules.

PIKAS--The center circle represents the pikas' rock tunnels. Each pika must venture out of its tunnels to gather and dry food for winter. Each pika must go out to the edge of the outer circle to pick up food cards, bring these back to the edge of the inner circle and place them in a pile to" dry in the sun". Pikas are only allowed to pick up one food card at a time. Once they have gathered and dried 5 food cards, they must carry their food into their tunnels. When all their food is safely in the burrow, they may remain inside and stay safe from the hawk. They must remain alert for the weasel and stoop down if it appears, however.

Pikas are vulnerable to weasels in the open and in burrows, but they can escape by hiding or stooping down. If a pika cries out when he/she sees a weasel, then the weasel may capture him/her, even if he/she stoops down. (A call gives away a hiding pika.)

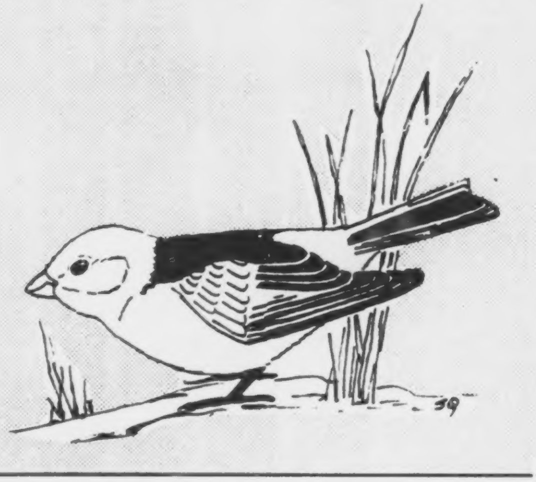
Pikas must give an alarm call when they see a hawk, and then run into their tunnels (the inner circle) to safety. Pikas should run for their tunnels whenever they hear an alarm call reporting that the hawk is around. The hawk may capture a pika even if he/she is stooping down. Hawks have sharp eyes.

HAWK--The hawk player remains outside the outer circle until he/she sees a vulnerable pika. Then, the hawk may go inside the outer circle and try to catch that pika--or any other unwary one. The hawk may not go inside the inner circle, however. A pika can escape the hawk by running into a tunnel (the inner circle), but not in any other way. After catching a pika, the hawk must run around the outer circle once before re-entering to catch another.
WEASEL--The weasel player catches prey by being sneaky. It quietly sneaks into the pika colony, and even into the tunnels. A weasel can catch any unwary pika inside or outside the burrows, unless the pika stoops down to hide before being tagged. A weasel may also catch a pika that calls out when it sees the weasel. After catching a pika, the weasel must run around the outer circle once before re-entering to catch another.

When a weasel or a hawk catches a pika, the pika is out of the game, gives the predator his or her tag, and joins the outer circle. The game should be timed and ended after 5-10 minutes. The winners of the game are any pikas that get 5 food markers and are not caught by a predator, and the predator that catches the most pikas. Play additional rounds so that all students eventually get to play.
A FURTHER NOTE: Pika players may try to steal food cards from their neighbors' haypiles. Although it is easiest to make this against the rules of the game, it is in fact a normal behavior for pikas. Individual pikas must be constantly on guard to prevent their hay from being stolen. They vigorously chase away possible thieves and spend a lot of time guarding their haypiles. If you want to allow stealing so that the game is more realistic, restrict players to stealing no more than one card at a time, and require that if a pika is caught in the act of stealing, the thief must immediately forfeit the stolen food card to its rightful owner. (The end result of stealing is usually that fewer pikas escape predators--they spend too much time watching other pikas and fail to notice the weasel or hawk.)

Tundra Topography.................. ....Art /Science ....Indoors

OBJECTIVES: Students will demonstrate their awareness of the topographical differences between alpine and lowland tundra by making clay models of both.
SKILLS: cooperation; ART: sculpture, painting
MATERIALS: modeling clay or play dough, paint brushes, paint, cotton, straw, or other art materials as needed to enhance the models.
PROCEDURE:
Divide the class into groups and ask each group to make a model of alpine or lowland tundra. Specify that each group should try to show all the features that are unique to the tundra type they are modeling. Encourage students to refer to the posters as well as books and other reference materials when planning their model. Be sure to have students look at the permafrost features pictured in the Supplementary Tundra Wildlife Cards section of this packet. Each group should make a list of the things they want to include in their model, so you can check it over and help them notice additional things to include. Ask students to divide up the task of making the model so that each student in the group has a specific task. (For example, one student might be in charge of making the snow, another in charge of rocks, another in charge of water, another in charge of animals, etc.)



ANIMAL ACTORS.................... ....Language Arts/Science ....Indoors/Outdoors

OBJECTIVES: Students will become more familiar with tundra animals while practicing dramatic communication skills.
MATERIALS: Tundra Wildlife Cards
PROCEDURE: Have students sit in a circle, with one student in the middle. The student in the middle draws a Tundra Wildlife Card and then tries to communicate the name of the animal to the group by acting it out. He/she can act like the animal, act out a "sounds like" message, or, as a last resort, try to spell out the name by acting out the letters of the name. Students should communicate their method by holding their hands on their heads to show they will act like the animal; tugging on their ears to show they will act out something that sounds like the name of the animal, or by putting their hands to their mouths to show they will spell out the name. If the class guesses the animal, the student should be praised and allowed to sit down. If a student has difficulty, he/she may tell the group, and draw a new card. You may wish to hand cards to students so you can give easier cards to shyer students or to those having trouble.

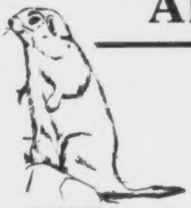
Wildlife Upset....................... Science / Language Arts............. ....Indoors/Outdoors

OBJECTIVES: Students will become more familiar with tundra wildlife, while practicing listening skills.
MATERIALS: Tundra Wildlife Cards, masking tape
PROCEDURE: Tape a wildlife card to the shirt of each student in the class. Sit the class in a circle on the floor, or you may have them sit in their chairs. Choose one student to be "It." Have the remaining students sit close together so there are no empty spaces between them. (If playing with chairs, place books on all the empty seats.) The It player comes to the front of the room or middle of the circle. He/she calls out the names of two kinds of tundra wildlife. The two students with the cards showing those animals must exchange seats. If the It player can get to one of the seats first, the displaced player becomes the new "It." If any "It" player is unable to get a seat after two tries, he/she may call out the names of three players. Also, if desired, any player may call out "Wildlife Upset." On this signal all players must change seats.

Worksheet 2a. Alpine Tundra Animals

Name______________________________

All of the animals shown below live in the tundra near the tops of mountains. Use the secret number code to find out the name of each animal.



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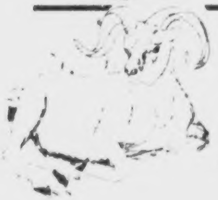
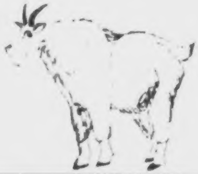


4,5 1,5 2,7 2,7 2,9 4,6 1,6 1,6 4,8



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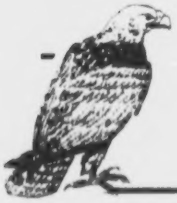
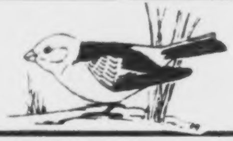


3,6 1,8 2,7 4,5 1,6 3,8 1,6 1,5 3,6 2,7 1,6



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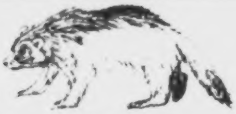

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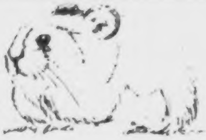
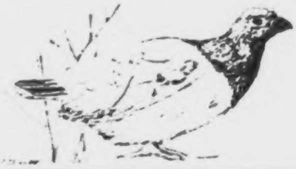
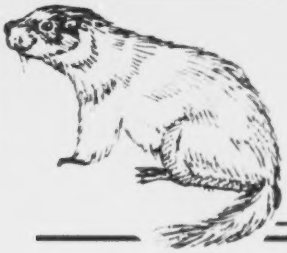
4,8 1,7 3,7 1,5



4,8 2,10 1,5 3,9 2,8 1,7 3,6 1,5 3,8



2,8 1,5 3,9 2,8 1,8 2,10



Secret Number Code

4	d	h	j	p	q	w
3	c	g	k	n	r	v
2	b	f	l	m	s	t
1	a	e	i	o	u	y
	5	6	7	8	9	10

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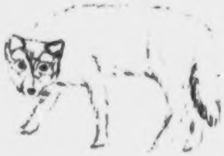
Worksheet 2b.
Name the Animals

Name___________________________________

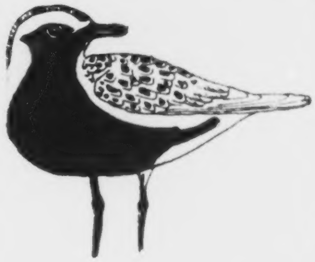
Match the pictures to the animal names. Write the letter of the animal name in the numbered blank next to its picture. Then, replace the numbers in the secret word with the letters they match . If your answers are correct you will find out where these animals live.

1.____

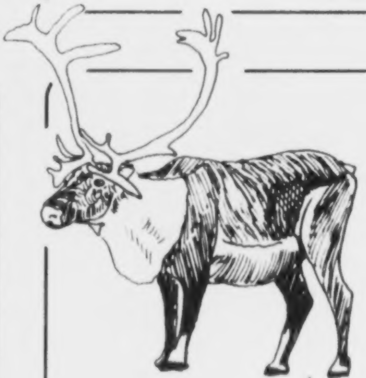


2.____

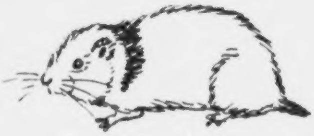
a. muskoxen
l. caribou
w. lemming
t. tundra hare
o. arctic fox
n. plover
u. goose
d. snowy owl



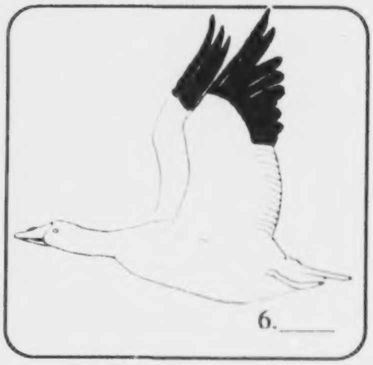
3.____



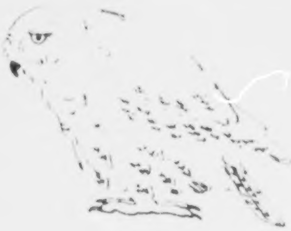
4.____



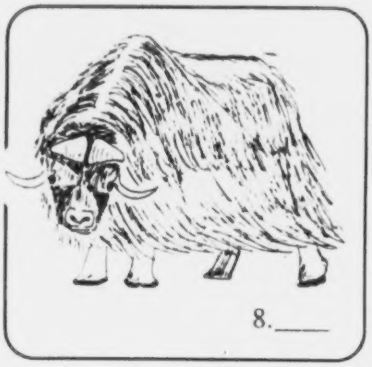
5.____



6.____



7.____



8.____

All of these animals live in ___ ___ ___ ___ ___ ___ ___   ___ ___ ___ ___ r ___.
4 2 5 4 8 3 7   1 6 3 7   8

This kind of environment occurs in western and northern Alaska.

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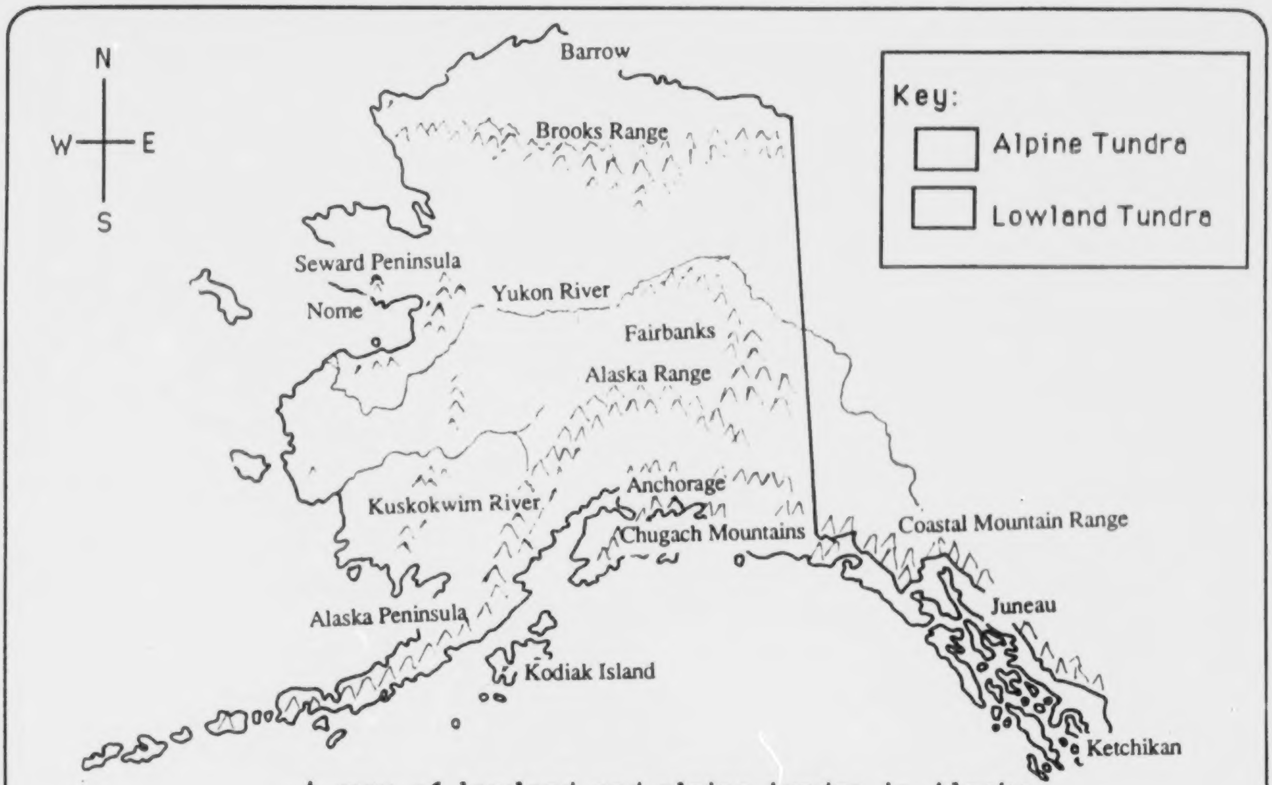
Worksheet 2c.
Alaska's Tundra

Name________________________________


N
W
E
S
Barrow
Brooks Range
Key:
☐ Alpine Tundra
☐ Lowland Tundra
Seward Peninsula
Nome
Yukon River
Fairbanks
Alaska Range
Anchorage
Kuskokwim River
Chugach Mountains
Coastal Mountain Range
Juneau
Alaska Peninsula
Kodiak Island
Ketchikan

A map of lowland and alpine tundra in Alaska.

This map is not complete. It shows our state, Alaska. It shows some of the larger towns in the state. It also shows the mountain ranges in Alaska. But it does not show where lowland and alpine tundra occur in Alaska. You can finish the map by coloring in the places where tundra occurs.

Use yellow to color in the places where alpine tundra is found. It is found on the tops of all the mountain ranges.

Use red to to color in the places where lowland tundra is found. It covers the plains north of the Brooks Range. It also is found on the coast of western Alaska. Most of the western Seward Peninsula and most of the Yukon and Kuskokwim River Deltas are lowland tundra. Lowland tundra also occurs on the southern Alaska Peninsula and on southern Kodiak Island.

If your home town is not on the map, add it to the map. Circle the kind of tundra occurs in or near your town. alpine lowland both kinds

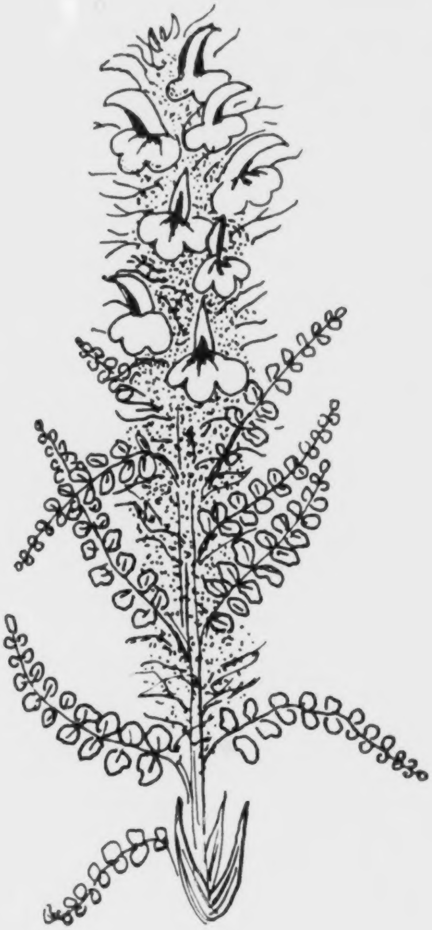
Be sure to color in the key to the map, so others will be able to understand what the yellow and red colors on the map mean.

Alaska Wildlife Week 1988. Alaska's Living Tundra. © 1988 ADF&G

Lesson 3.

Vocabulary:

adaptation, dormancy, hibernation, migration, staging



Objectives:

Students will recognize that the living things that occur in tundra environments are able to survive the long, cold winters because they have special traits, or adaptations.

Teacher Background:

Biologists call the physical, physiological, and behavioral traits that help an organism survive in a particular environment, "adaptations". Organisms that live in tundra environments must have adaptations to help them survive and raise young despite the periodic severe cold, persistant winds, short growing season and other difficulties posed by this severe environment.

The following pages provide some specific examples of the amazing adaptations that allow specific living things to live and flourish in Alaska's tundra ecosystems.

Alaska Wildlife Week 1988. Unit 6. Alaska's Tundra. © 1987 ADF&G

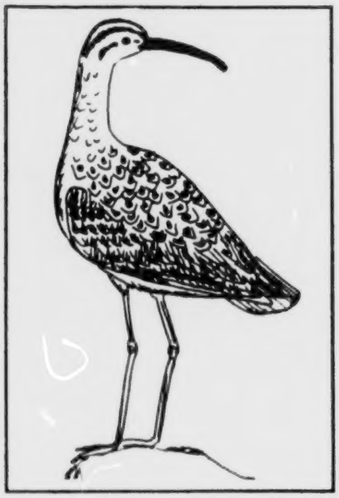
Migration is an adaptation for avoiding the severe winter conditions of tundra environments.

Many living things are able to live seasonally in tundra environments by avoiding the period of severe cold and strong winds by migrating to an environment with less harsh conditions. The seasonal gatherings and movements of large numbers of animals into and out of tundra environments are among the most spectacular natural events in the world. Each spring, huge flocks of shorebirds and waterfowl rush toward the tundra. Areas that were barren of life in winter can come alive with the movements and calls of arriving migrants almost overnight. These birds spread out over the tundra expanses to nest. Only in late summer and fall, when these avian migrants and their young gather together before hurrying south, is the surprising productivity of the tundra expanses revealed. The gathering places of migrants, called staging areas, occur in the same places year after year. Usually they are in locations that provide abundant food, so the migrants can fuel-up for their long-distance travels. Some migrant birds nearly double their weight with layers of fat before leaving.

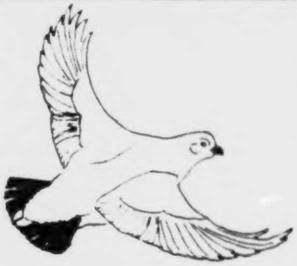
Many birds travel thousands of miles to wintering areas in Central and South America or Polynesia. The arctic tern migrates 10,000 miles (16,094 km) to winter in Antarctica. Some birds, like ptarmigan, migrate relatively short distances. They move south out of arctic tundra areas, and downslope from high alpine areas to low alpine or forested areas.

The migration of caribou from tundra areas to more southern forest environments is one of the best known examples of migration by a mammal. Their annual movements may, in part, be an adaptation for avoiding the severe winter conditions in tundra. The crusty snow pack that covers many tundra areas in winter makes it difficult for caribou to uncover food. However, some caribou do not migrate, but instead remain in tundra year-round.

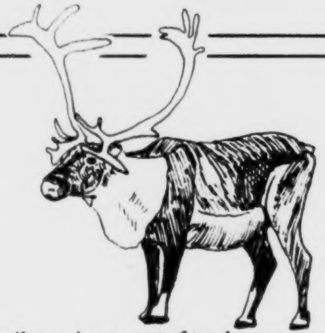
Many tundra fish also migrate. In fall, they move into places where the water does not freeze solidly in winter. Deep lakes, deep channels in large rivers, and spring-fed streams are important over-wintering areas for tundra fish.



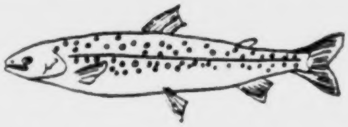
Whimbrels nest in tundra but migrate to spend the winter on the Pacific coast from California to Chile. Most shorebirds migrate thousands of miles to southern wintering areas.



Ptarmigan migrate out of the northernmost tundra regions to winter in the alpine tundra and forests of central Alaska.

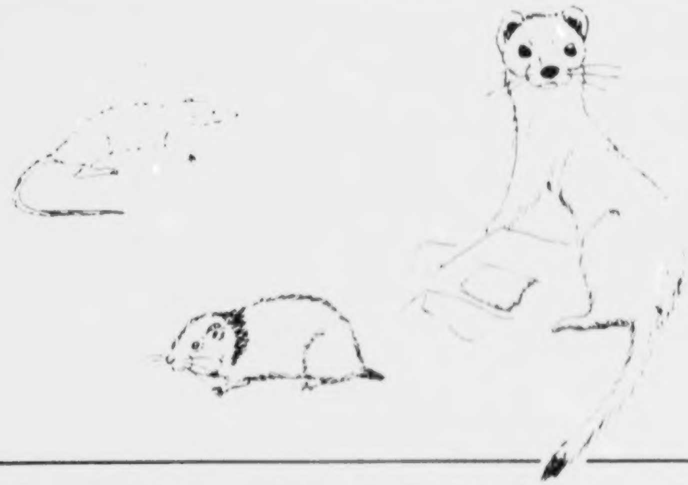


Caribou migrate out of tundra areas to winter in more southern taiga and forests.



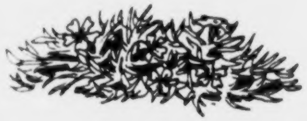
Tundra fish, such as arctic char, migrate to places where some water remains liquid throughout winter.

Many living things remain on the tundra year-round, but avoid the severe winds and cold.



Lemmings, voles, shrews, weasels, arctic ground squirrels, insects and most plants survive the winter winds and cold by living beneath the snow. Temperatures under a blanket of deep, soft snow are usually 20° F (34° C) warmer than the air temperature above the snow. However, in tundra areas with crusty, windblown snow, the under snow temperature may drop to -31°F (-35° C).

The small mammals, insects, and plants that live in tundra cannot make long distance journeys to avoid the severe winter conditions of tundra. Many of these winter residents avoid the severest winter conditions by remaining beneath the snow. For example, lemmings tend to concentrate in areas where the snowpack is greatest. The snow shelters them from the wind. It also offers some protection from the cold of winter. However, the dense, wind-packed snow of arctic tundra is a poor insulator and provides only limited protection from the cold. (In contrast, where the snow is protected from wind, it is deeper and less dense and provides much better insulation.)



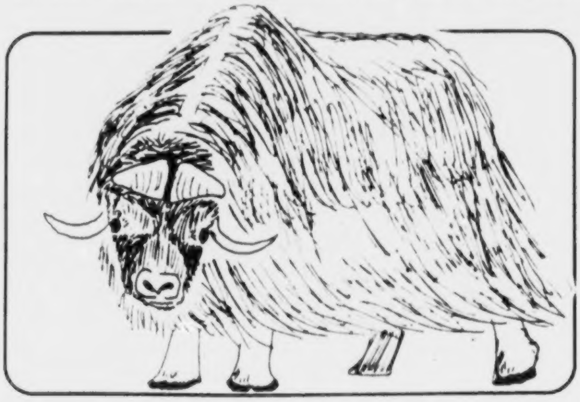
Air temperatures near the ground are warmer and winds are slower near the ground surface. Many tundra plants, such as moss campion, grow in low, flat mats or cushions to take advantage of these milder conditions.

Some animals, like the arctic ground squirrel, move underground for winter. Soil, like snow, provides insulation against the cold and wind. Many plants have a similar adaptation; their above ground parts die back each winter, but their main growth and energy storage is in their underground roots, which, sheltered by the soil and snow, survive the winter cold and winds.

Environmental conditions on the tundra are most severe during winter, but cool temperatures and strong winds during summer also pose problems to living things. The adaptations of many living things enable them to avoid the cold and wind year-round. For example, many tundra plants are small and grow in flattened, cushion-like forms. Due to friction, the wind speed an inch or two above the ground is much less than the wind speed farther above the ground. The air is also warmer near the ground than above it because soil absorbs and radiates heat from the sun. Many kinds of insects live their entire lives in the shelter of ground plants, thus avoiding the most severe cold and wind of the tundra. Wingless forms of many insect groups are most common in tundra environments. Arctic ground squirrels and brown bears select south-facing slopes in which to dig their underground dens. These sites are warmer than north-facing slopes during fall and spring.

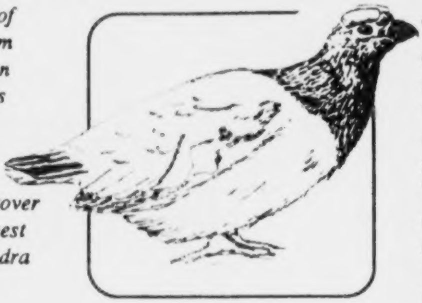
Wingless insects are common in tundra environments. They spend their entire lives in the shelter of soil, mosses, or other plants.

Most tundra organisms have insulation to help them stay warm.



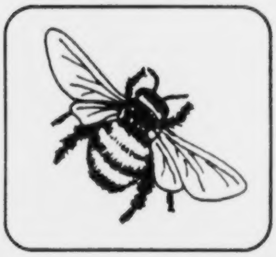
The long, dense fur of muskoxen helps them stay warm even when the air temperature is -40°F (-40° C).

One of the most obvious adaptations for life in a cold environment is insulating feathers or fur. Most tundra birds and mammals actually have two coats. Their outer coats are made up of tough, coarse water-repellent feathers or guard hairs. Their inner coats are made up of soft, fluffy feathers or hairs that trap air. Ptarmigan can keep their body temperatures at 104° F (40°C), (without increasing their respiration rate) even at temperatures of -29° F (-34° C). Caribou and muskoxen have hollow hairs that are fatter at the tips than at the base. This shape helps the hair trap a layer of air next to the body. Trapped air provides excellant insulation.



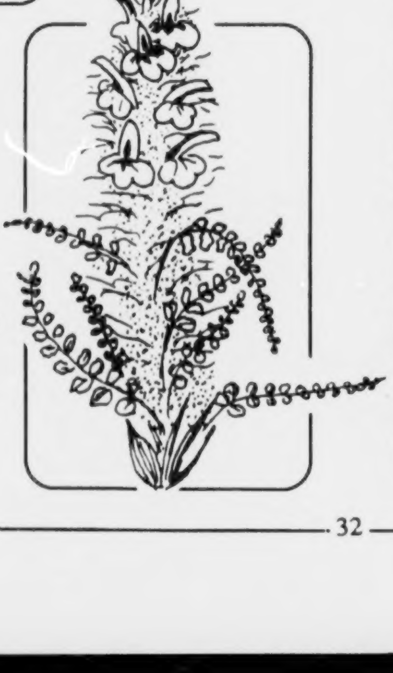
Ptarmigan, whose feathery coats even cover their feet, have the best insulation of any tundra bird.

Tundra bumblebees provide a fascinating example of the adaptive value of an insulative coat. Insects are cold-blooded or poikilothermic organisms, which means that their body temperatures are closely related to the temperature of their surroundings, and rise and decline accordingly. The chemical reactions necessary for movement do not occur at cold temperatures, so most insects can not move unless the temperature is above freezing. However, dense hair on the bodies of tundra bumblebees slows heat loss from their bodies to the air. Certain bumblebees "shiver" their flight muscles to generate heat. This heat is temporarily trapped within the bee's velvet coat. Certain bumblebees can keep their body temperatures 68-86°F (20-30° C) above air temperatures, and thus can easily be active when other insects are too cold to move.



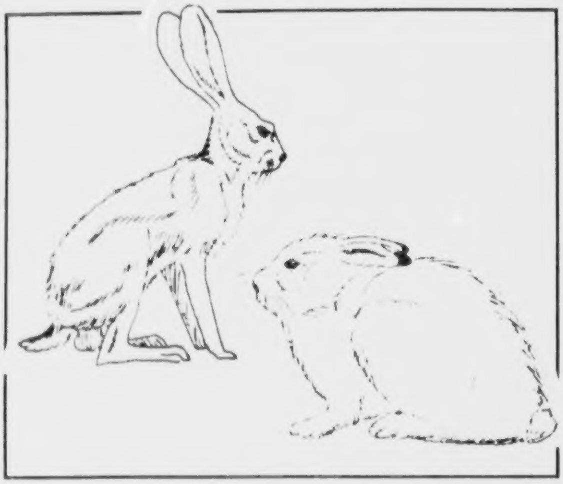
Tundra bumblebees have dense velvet-like hair that helps them keep the heat released when they move their wing muscles.

The furry and wax-like coatings of certain tundra plants are also adaptations that enable the plant to resist cold and wind. Fine hair or fuzz slows the wind and thus reduces the "wind chill" or loss of heat. The fine dense hair around the flowers of the wooly lousewort not only reduce wind chill, but also trap heat from sunlight like the glass of a greenhouse. The flowers are thus surrounded by relatively warm air, sometimes 34° F (20°C) warmer than the environment. This is quite important because the process of cell division, necessary for the formation of seeds, can not occur at cold temperatures. The waxy coating of many plants reduces water loss and evaporative cooling by the wind. Many tundra plants retain, rather than shed, their dead leaves each year. The dead leaves serve no apparent purpose except they insulate the fragile new buds from the wind and cold. Grass tussocks provide a good example of this.



Wooly lousewort, a tundra plant, is covered with hairs that help block the wind and trap warm air around its leaves and flowers.

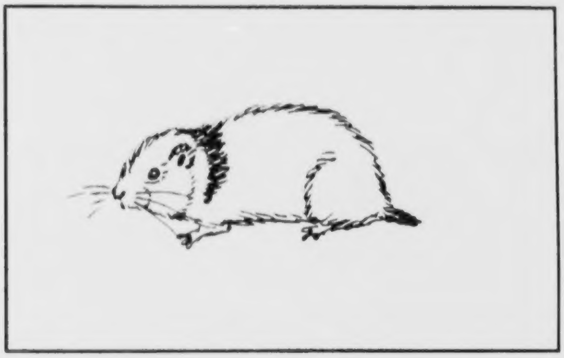
Large size and short appendages are adaptations that help tundra animals keep warm.



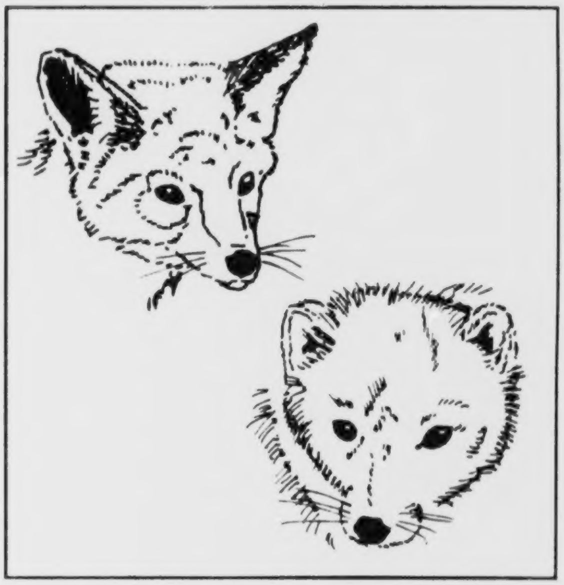
Tundra hares are larger and have shorter ears than hares that live in hot environments.

Biologists have noticed that many tundra birds and mammals are larger and have smaller appendages than similar species living in warmer environments. For example, tundra hares are among the largest hares and have shorter ears and legs than desert hares (called jackrabbits). Similarly, arctic foxes have shorter ears than desert kit foxes. Even lemmings, though small, are larger, and have smaller ears and tails than most other mouse-like animals. Large size and short appendages are adaptations that reduce heat loss and resist cold. The amount of heat lost increases as the proportion of surface area exposed to the environment increases. Since small animals have more surface relative to their weight than large animals, they lose heat more quickly. An animal with long legs, ears, or a tail has more surface area than an animal of the same size but with shorter appendages.

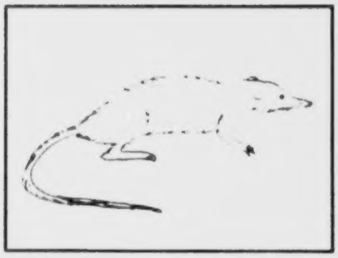
However, small size can also be an adaptation for survival on the tundra. Why? Because a small organism can survive on a smaller, total amount of food than a large organism (of the same species). Very small organisms can also live under the snow and avoid the most severe conditions of winter. Shrews, the smallest of all mammals, are able to live in tundra of arctic Alaska.



Lemmings are larger, and have smaller ears and tails than most other mouse-like animals.



Arctic foxes have shorter ears than desert kit foxes.



Small animals like shrews are able to keep warm despite their small size, in part because they can live under the snow.

The coloration of living things in the tundra are adaptations to their cold environment. Which is warmer, dark or light?

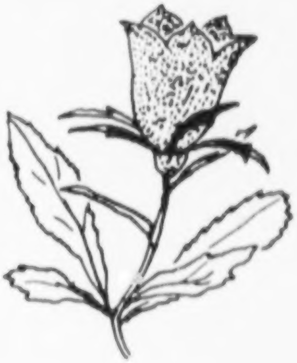
Dark colors absorb heat, while light colors reflect it. Thus, one might expect that organisms that live in cold tundra environments would be darker than organisms living in warmer environments. A study of flowering plants showed that the proportion of dark colored flowers is greater in the tundra than in warmer environments. Many tundra flowers are purple, blue, or yellow because these colors absorb more heat than white. Certain tundra insects are darker than related species that occur in warmer habitats. The value of dark color can be increased by an organism's behavior. For example, many butterflies bask in the sun with their dark wings spread wide to absorb heat.

Thus, among organisms whose temperatures are strongly influenced by the environment, dark colors can be an adaptation for survival in a cold environment.

However, the light coloration of arctic poppies (and other flowers) is an adaptation to the cold environment, too. The flowers of these plants are heliotropic, meaning they turn to face the sun. The shape of the light petals are such that they reflect sunlight toward the flower center where the seeds are produced. Several kinds of insects bask in the centers of these flowers, and benefit from the focused solar heat.

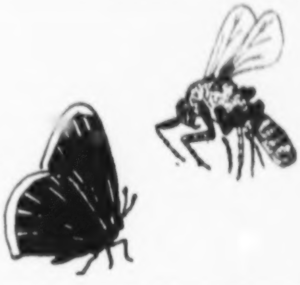
Many animals that maintain warm body temperatures (homeotherms), such as birds and mammals, have light, or white, feathers or fur. Their light coloration also may be an adaptation for staying warm. These animals generate their own heat, but lose heat when it radiates to their surroundings. Light colors radiate less heat than dark colors, so light fur and feathers actually may help warm-blooded tundra animals keep warm!

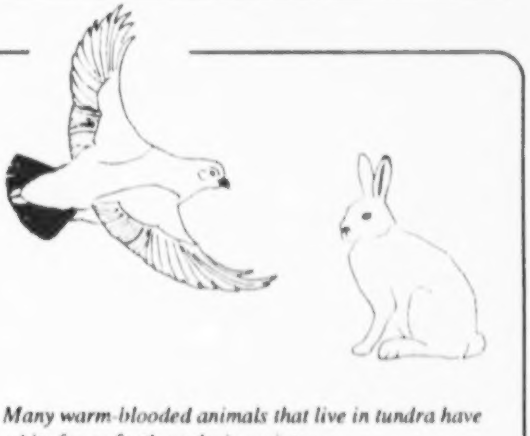
White fur and feathers also camoflauge animals in the snow. Thus white coloration may help collared lemmings, ptarmigan, and snow buntings escape their predators, and help snowy owls, weasels, and arctic foxes sneak up on their prey.



More tundra plants have blue or purple flowers than plants in warmer environments.

Most tundra insects are darker than related insects in warmer enviornments.





Many warm-blooded animals that live in tundra have white fur or feathers during winter.

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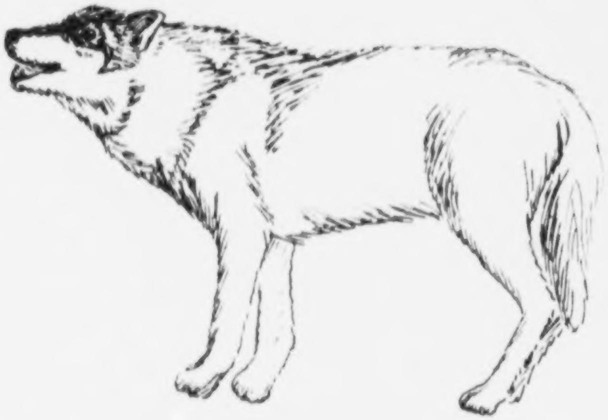
Introductory Activity 3.



Objective:

Students will recognize that the living things that occur in tundra have special traits and behaviors (i.e. adaptations) that enable them to survive in this environment.

Skills:

SCIENCE: comparing, predicting, inferring
LANGUAGE ARTS: reading, oral communication

Materials:

Adaptation Cards in the Tundra Wildlife Cards supplement to this packet, blackboard, chalk, masking tape.

Procedure:

SUMMARY: Students will use information about specific traits (or adaptations) of animals to determine which living things (pictured and described on the Adaptation Cards) live in tundra.

1. PREPARATION: Cut out and laminate the Adaptation Cards.

2. PASS OUT THE ADAPTATION CARDS: Divide the class into groups of 2 or more. Place at least 1 pair of adaptation cards (matching symbols) picture side down on a desk in front of each group (or place tape over the name of the animal and its environment to hide this information). Students should read the cards, but not turn them over. The groups should discuss the information provided on the cards and be prepared to place one card under a "Lives in A Tundra Environment" category, and the other in a "Lives in A Different Environment" category. They should also be able to explain why they placed the cards in the categories. (ALTERNATIVELY: If all students' reading skills are not adequate for the above task, you might place one good reader in each group, OR read the sets of cards aloud, and discuss the problem as a class instead of having student groups work independently.)

3. STUDENTS PLACE THEIR CARDS IN THE APPROPRIATE CATEGORY. Write two headings on the board: "Lives In A Tundra Environment", and "Lives In Some Other Environment." Then have one student from each group come up to the board, read their cards to the class, then place them in the categories their group decided upon. Have the class vote whether they agree or disagree with the placement. If they disagree, have the student describe the group's reasons for classifying the cards as they did, and have dissenters from the class explain their reasons for disagreeing. Then, turn the cards over to show the described animals or plants, and find out the correct placement. Tape the cards to the board under the appropriate categories. Repeat until each group has correctly placed their cards.

4. ASK STUDENTS WHAT SIMILARITIES THEY CAN FIND AMONG THE TUNDRA ORGANISMS. Students should recognize that all the organisms that live in tundra have traits that help them survive in the tundra environment. For example, many have traits that help them keep warm--e.g. long hair or dense feathers. Explain that traits that help an animal or plant survive in its environment are called "adaptations."

Use questions to help students realize that the living things found in other environments also have adaptations. Though not helpful for life in the tundra, the described trait of each living thing is helpful for life in the kind of environment in which it lives. Briefly discuss the adaptations to other environments which the living things under the "Other Environments" category have. (Living things that live in the desert have adaptations that help them survive heat; those that live in the ocean have adaptations for swimming and keeping warm in the water; those that live in forests have adaptations that help them take advantage of the food and cover provided by trees.)

EXTENSIONS: All of the Curriculum Integration Activities further develop the concept of adaptations and can be used for reinforcement or evaluation of student understanding.

Evaluation:

Students complete Worksheet 3.

HUMAN ADAPTABILITY....................................SOCIAL STUDIES / SCIENCE ....Indoors

OBJECTIVES: Students will recognize that humans cope with their environments by using tools and learning.
SKILLS: reading, comparing, inferring.
MATERIALS: Blackboard, chalk, reference materials about people living in the arctic.
PROCEDURE:
1. REVIEW THE PROBLEMS FACING LIVING THINGS IN A TUNDRA ENVIRONMENT. Write on the blackboard "Problems of Living in the Tundra" as the heading of a column. Ask students to list some of the problems faced by organisms that live in tundra environments. With prompting, students should be able to list Cold Temperatures, Long Winters with Little Food, Short Growing Seasons, and Wind. List these on the board.

2. REVIEW PLANT AND ANIMAL ADAPTATIONS FOR TUNDRA LIFE. Write "Animal and Plant Adaptations to the Tundra" as the heading of a second column to the right of the first. Ask students how tundra organisms are able to survive these problems. Students should be able to describe some of the traits, or adaptations, of tundra organisms which allow them to tolerate the "problems." List the adaptations named under the second column heading next to the related "problem." (If students can not describe some of the adaptations of tundra organisms, hand out the adaptation cards that show tundra animals and plants. Ask students to read the cards and then name some of the traits that help organisms survive in the tundra.)

3. DISCUSS WAYS HUMANS COPE WITH LIFE IN THE TUNDRA: Write a third column heading on the blackboard: "Human Methods of Surviving in Tundra." Then ask students to list specific ways that humans deal with the same problems that other tundra organisms must face. (E.g., Problem: Cold--people wear coats, build warm houses, use fire, or migrate (by going to Hawaii or the Lower 48); Long Winters with Little Food--people store food from summer; bring food in from elsewhere, or go elsewhere to find food.)
OPTIONAL: Have students use reference materials (books, encyclopedias, etc.) to learn how humans survive in tundra environments around the world.
4. DISCUSS THE SIMILARITIES AND DIFFERENCES BETWEEN ANIMAL AND PLANT ADAPTATIONS, AND HUMAN METHODS OF SURVIVAL IN TUNDRA. Students are likely to see the similarities between the ways other living things are adapted to the tundra and the ways humans survive. However, it is also important that students recognize the differences.

Animal and plant adaptations are genetically determined--meaning that tundra organisms do not choose, or decide, to grow thick fur for winter, or migrate, or grow large, or turn white. Adaptations are genetic traits, just like the colors of student eyes and hair, or student height, foot size, etc.

In contrast, most of the human methods of surviving in tundra environments are matters of choice. A person decides whether to "migrate" or stay through winter; whether to wear warm coats or stay in a warm house; whether to gather and store extra food during summer, have extra food shipped in from elsewhere, or go elsewhere to find food.

Encourage students to discover and understand this contrast by asking them whether or not an arctic fox (for example) could decide to migrate south. Could a plover decide to store food, grow a thick coat of warm feathers, and stay through the winter instead of migrating? If you planted the seed of a cushion plant from the tundra in a place with no wind, would it grow tall? Could a caribou "adapt" to a hot, dry desert environment? (If students have difficulty grasping that these adaptations are not decisions made by the plants and animals, ask them whether they could decide to grow a fur coat, or turn white in winter. They will soon realize that an animal or plant could not do so either.)

What about the methods people use to survive? Could an Inuit Native move to the desert and survive? Or, could someone from the tropics survive in the arctic? How? (By learning human methods of dealing with that environment.) Discuss the implications of this difference. Could tundra plants and animals survive if the tundra environment was somehow changed?

NOTE: Races of humans that have lived in a particular environment for thousands of years also have genetic adaptations to their environments. For example, the relatively small stature and build of arctic people are adaptations for surviving in cold and with less food during the long winters and food shortages typical of the north. Twilight vision (and associated color blindness) is more common in races of arctic people than in races of people who live at lower latitudes. This represents an adaptation for use of the long twilight periods that occur at high latitudes. Races of people native to tropical climates have physiological adaptations for resisting some of the diseases of their environment.

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PROGRESSIVE ANIMALS

....Art / Science
....Indoors/Outdoors

OBJECTIVES: Students will demonstrate their understanding of the term adaptation while cooperatively creating imaginary animals "adapted" to various environments.
MATERIALS: Drawing paper, colored pencils
SKILLS: Cooperation, drawing, creativity, application of science concept

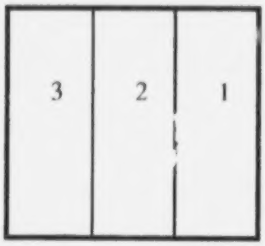
PROCEDURE:
1.STUDENTS PREPARE PAPER: Divide the class into groups of 3 and give each group 3 sheets of paper. Ask them to fold each sheet of paper into thirds as shown.
Explain that students in each group are going to work together to create 3 imaginary animals with adaptations for living in a specific environment. (For simplicity, you may want all drawings to show animals adapted to the tundra. But, if students are capable of it, you may want to label each paper with a different environment (Tundra, Desert, Forest, or Ocean) and have students invent 3 animals adapted to different environments.)

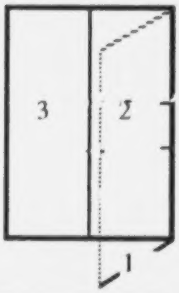
2. STUDENTS DRAW ANIMALS ADAPTED TO THE NAMED ENVIRONMENT: Ask students to think carefully about the tundra (or other environment) and the adaptations that animals have for life in that enviroment. Then, ask each student to imagine the head of an animal adapted to that environment. Ask each student to draw the head on part 1 of their page. The animal should be looking to the right and must have a neck that extends over into part 2 of the page. Encourage them to think about whether the animal should have a long or short nose, long or short ears, thick or thin fur or feathers, etc. When students are done with the head (allow 5 minutes), they should fold part 1 of the paper so that it is hidden.

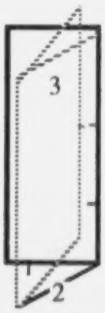
This folded paper should then be passed the third person in their group. That person should continue the drawing by adding the forelimbs and middle body of an animal adapted to the tundra. The middle body must connect to the neck drawn previously, and should extend just into part 3 of the paper. Encourage students to think about the need for insulation, whether the organism migrates, how it gathers food, etc. when designing the animals forelegs When students are finished, part 2 of the paper should be folded under, so that only part 3 of the paper remains showing.

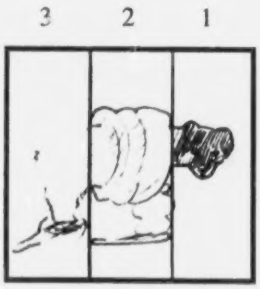
Once again, they should pass their papers to the right. This time each student should draw the hind limbs and tail of an animal adapted to the tspecified environment. Encourage students to think whether their imaginary animal runs, wades in the water, or swims. They should also consider whether its tail is long or short and how it is used.

3. STUDENTS DISPLAY IMAGINARY ANIMALS: Each group will have completed 3 animals adapted to the tundra, (or to 3 different environments if you chose the optional method in Step 1). Have groups discuss their animals and have each artist explain why they drew specific features.
OPTIONAL EXTENSION: Have the group select their favorite from the 3 creations and then write a life history for the animal. Their life history should describe the size and weight of the animal, what it eats, what eats it, and how it is adpated for the life it leads.







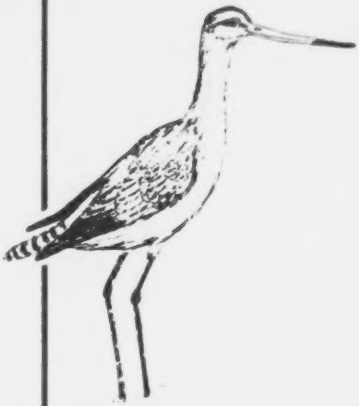


TUNDRA ADAPTATIONS.......LANGUAGE ARTS

OBJECTIVES: Students will be able to identify some of the adaptations of tundra animals and plants.

SKILLS: reading comprehension

MATERIALS: Adaptation Close-ups (see following pages), crayons
PROCEDURE:
Have students read the Adaptation Close-ups and color in the pictures. You may have each student read all of the papers, or assign separate ones to individuals. Individuals could then report what they read to the class. Have students complete the Reading Comprehension Worksheet for each of the close-ups they read. This can be used to evaluate reading comprehension. (Alternatively, read the information aloud and have students color in the pictures



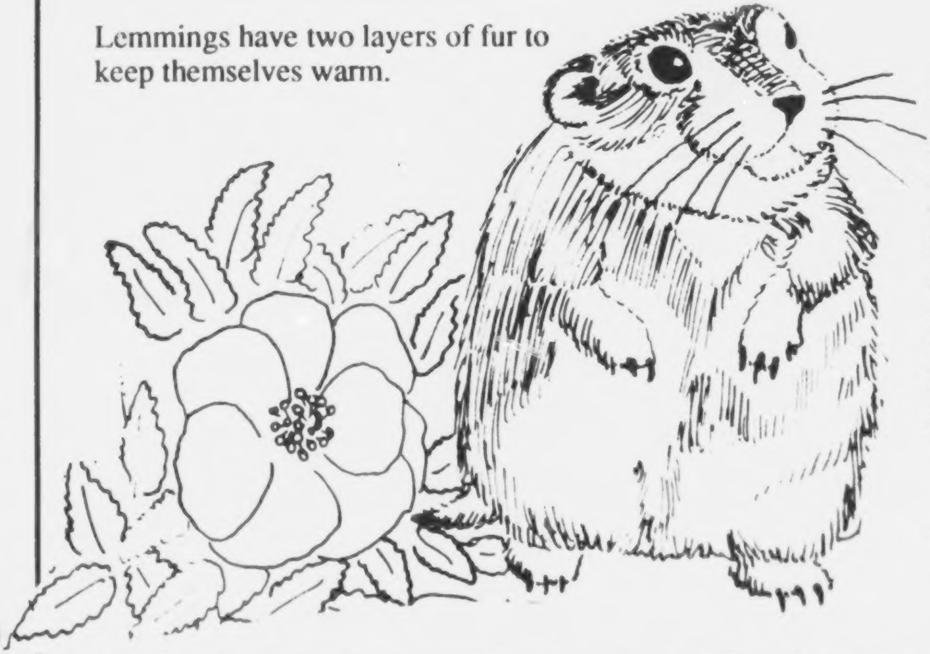
MICROHABITATS..
OUTDOORS..SCIENCE

OBJECTIVES: Students will recognize that environmental conditions vary considerably even within a small area, and that living things seek out sites with the most tolerable conditions.
SKILLS: observing, comparing, inferring
MATERIALS: clear plastic bags (non-leaking), felt-tip pens (that draw on plastic), rubber bands, gelatin, boiling water, a measuring spoon (1 Tablespoon); Optional: thermometers, anemometers
PROCEDURE:
1. PREPARATION: Dissolve 1 package gelatin in 1 1/2 cup boiling water. Set aside to cool but do not allow to set up.
2. STUDENTS PREPARE GELATIN ANIMALS: Give each student a plastic bag. Ask them to draw a picture on the plastic bag of a small tundra animal. Then, have each student put 2 Tablespoons of gelatin in their bag and seal the bag shut with a rubberband.
3. STUDENTS FIND A PLACE FOR THEIR ANIMAL TO LIVE. Ask each student to put their animal in a spot where they think it could live. Wait 10 minutes, then have students check on their animals. Did any of them "freeze" (gel)? What kinds of places were these animals in? Explain that if an animal freezes, it can't live. So, tundra animals try to find places where they won't get as cold. Allow students to move their animals to new places if they want. Then recheck the animals every 3-5 minutes. Which animals stayed unfrozen the longest? What was different about the sites these animals were in? Were they warmer? Better insulated? More sheltered from the wind?
4. STUDENTS COMPARE THE SITES. Have students measure the temperature and wind speed at the sites where the animals froze quickly and compare these to the sites where the animals froze more slowly. Do they find any differences? If the temperatures and wind speeds are the same, what about the insulation at the two sites? Would an animal stay warmer in a nest of grasses or in the same spot without a nest? In a nest of eider down? Why? (The nest would be warmer because it provides insulation, thus trapping heat released by the animal. Thus the animal wouldn't lose heat as quickly and could stay warm longer.)
5. STUDENTS LOOK FOR EVIDENCE OF ANIMAL USE OF MICROHABITATS: Have students explore the area and look for animals and plants that make use of sheltered spots and insulation. Can they figure out some good places to look for insects and signs of other animals based on what they now know about microhabitats?

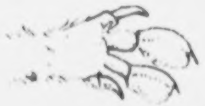
CREDIT: This activity is adapted from Outdoor Biological Instructional Strategies, Lawrence Hall of Science, University of California, Berkeley, California; see the reference list for information on obtaining these excellant educational materials.

Collared lemmings have adaptations that help them live in the tundra.

Lemmings have two layers of fur to keep themselves warm.

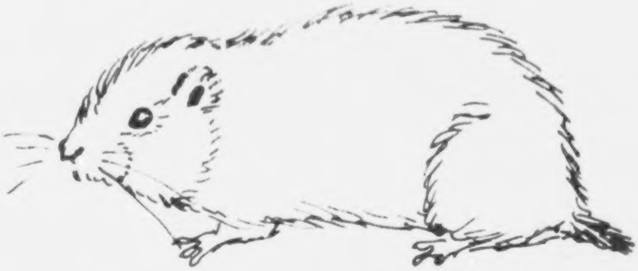


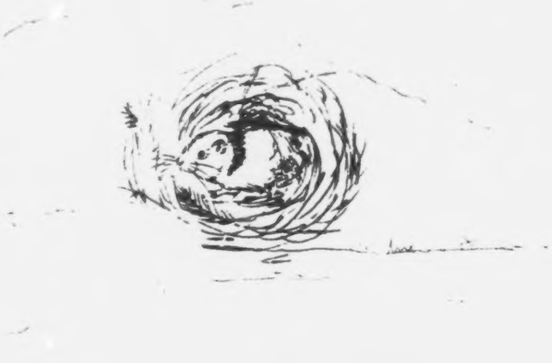
Long ears and a long tail would soon freeze in the icy cold of a tundra winter. Lemmings have short ears and a short tail. Both are covered with fur. Color this lemming brown for summer.



Collared lemmings grow special claws on their front feet every winter. They use these claws to dig tunnels through crusty snow. By living under the snow, lemmings avoid the wind. The air is usually warmer under the snow, too.

Lemmings build nests of mosses and grasses under the snow. The snow and the nest help them stay warm even on the coldest winter night.

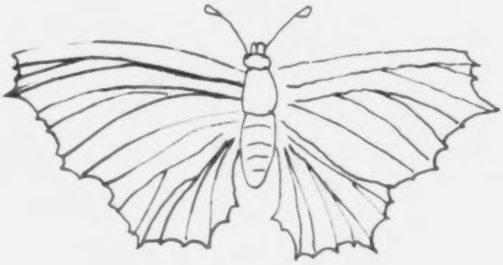




Collared Lemmings are the only mouse-like animals that turn white in winter. Their white fur allows them to stay warm and hide from predators.. Color this lemming white for winter.

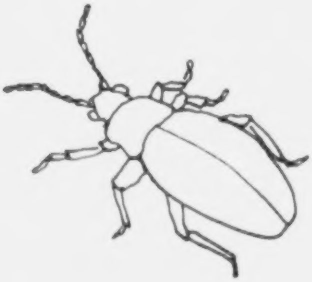
Insects that live in the tundra have adaptations that help them survive.

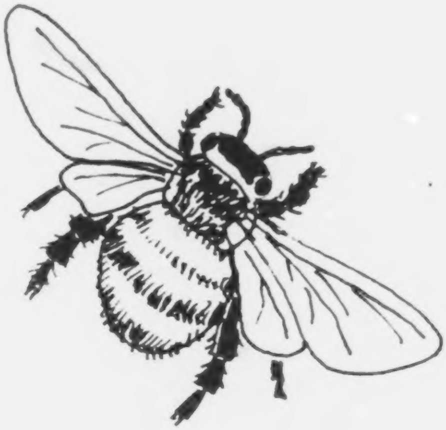
Most tundra insects survive winter as eggs. Eggs are able to withstand freezing cold and dryness better than adult insects.



Many tundra insects have dark bodies and wings. Their dark colored bodies soak up heat from sunlight. Color this butterfly dark brown.

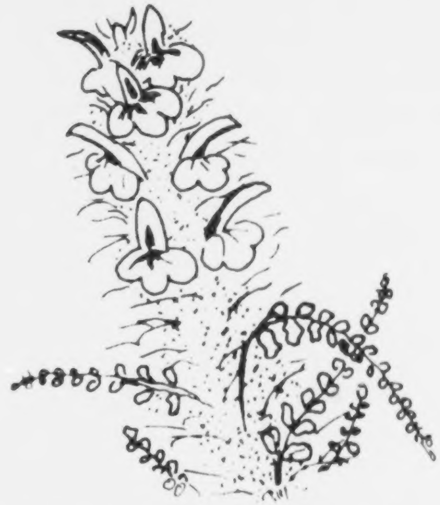
Many tundra insects make special chemicals, called antifreezes. These chemicals prevent the insect from freezing solid in the cold winter. Color this beetle black.





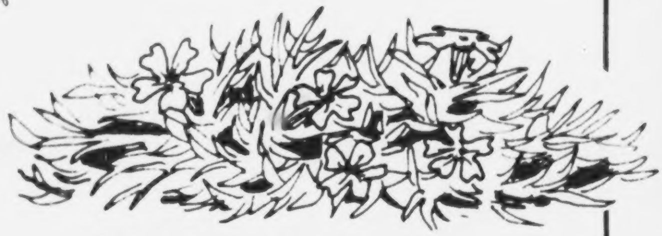
Tundra bumblebees have a coat of velvet hair. This coat helps them stay warm. They also have special muscles that they use to make heat. These traits allow bumblebees to fly around when most other insects are too cold to move. Color this bee yellow, orange, and black

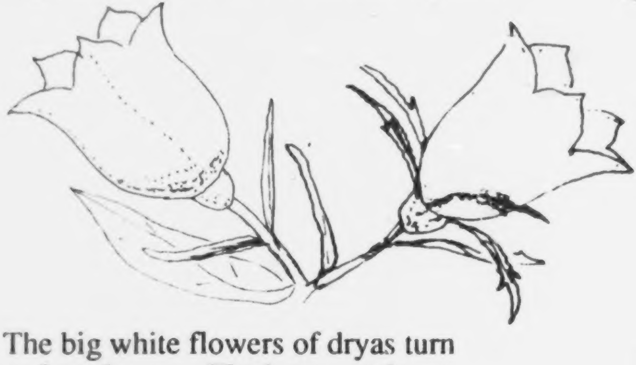
Tundra plants have adaptations that help them live in the tundra.



Wooly lousewort is covered with hairs. The hairs block the wind. This helps keep the plant warm. Color its flowers light purple.

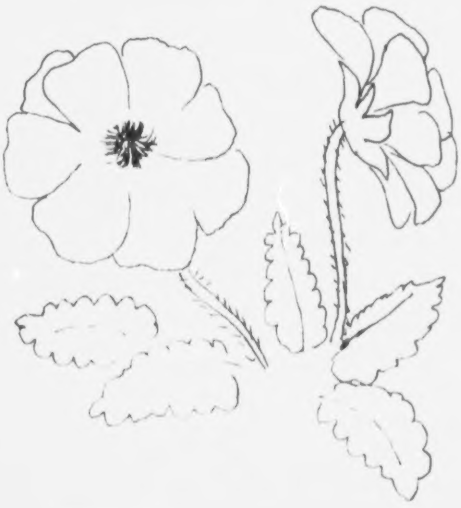
Many tundra plants, like moss campion, only grow a few inches tall. The wind does not bother them because they grow so close to the ground. Color its flowers dark pink.





The big white flowers of dryas turn to face the sun. The large petals act like mirrors. They reflect sunlight toward the yellow center of the flower. This keeps the seed-making parts of the flower warm. Some insects stay warm by living in the center of these flowers.

Many tundra flowers are blue, red, or purple. Dark flowers soak up heat from the sun. So, they get warm on sunny days. Color these flowers blue.



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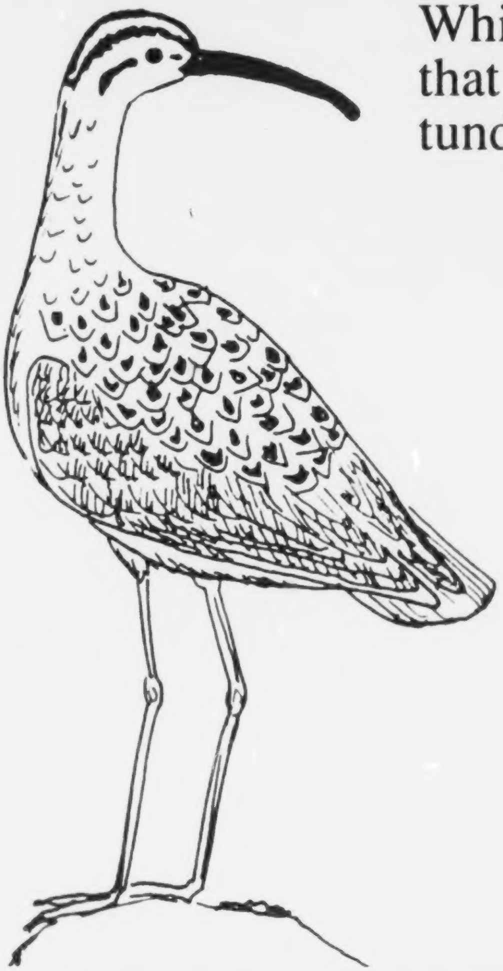
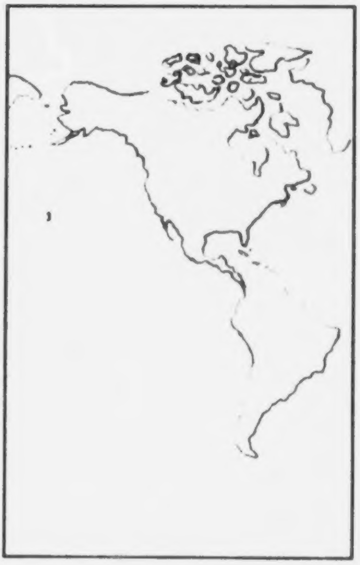


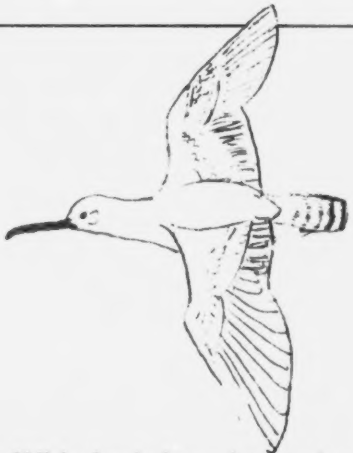
Whimbrels have adaptations that help them live in the tundra.

Whimbrels use their long bills to find insects hiding in the mosses and lichens of tundra . They also use this bill to probe for insects and other small animals that live in the mud along lake and ocean shores.

Whimbrels nest on the ground in tundra. Their feathers and their eggs match the color of tundra lichens and grasses. This helps camouflage them from predators. Color this whimbrel brown.

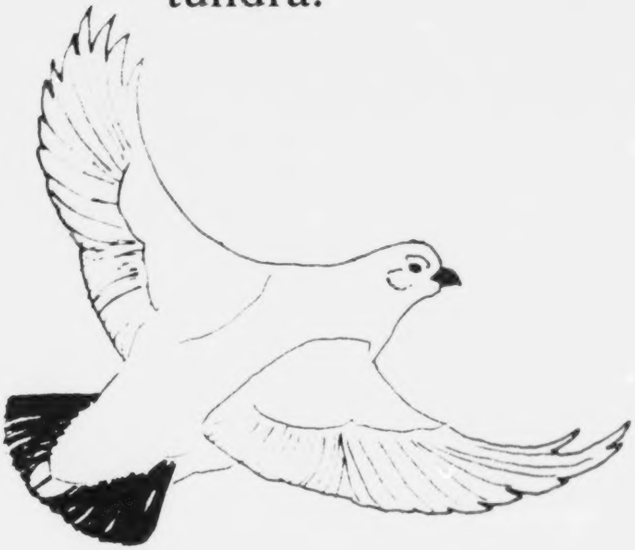
Whimbrels nest in tundra. They do not stay for the long, cold winter. Instead, they survive by migrating south. They spend the winter in the warm climates along the coasts of Mexico and Central and South America. Color the land green and the water blue.





Whimbrels have long wings and hollow bones. These traits allow them to fly long distances.

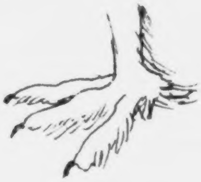
Ptarmigan have adaptations that help them live in the tundra.



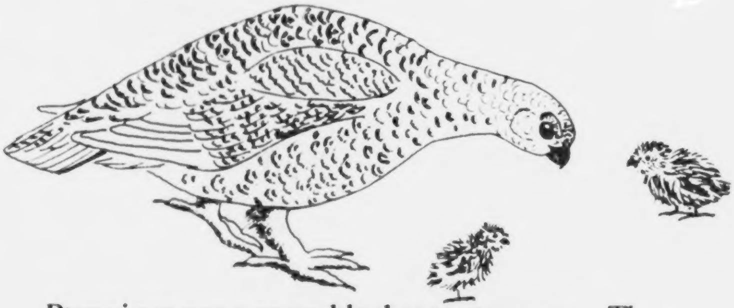
Ptarmigan have two layers of feathers to keep them warm. They can stay warm when the air temperature is 50 degrees below zero.

A ptarmigan in winter.

Ptarmigan have feather snowshoes! In winter, they grow large feathers on their feet. These feathers keep their feet warm and help ptarmigan walk on top of soft snow.



A ptarmigan in summer .



Ptarmigan are brown in summer. They turn white in winter. Their colors help them hide from predators. Color in the two pictures of ptarmigan.

Ptarmigan use a snow blanket to stay warm. They burrow into the snow at night and on very cold days. The snow traps warm air and blocks the wind. This helps the ptarmigan stay warm.

READING COMPREHENSION WORKSHEET--ADAPTATION CLOSE-UPS

LEMMING

1. A lemming is a bird a fish a mammal
2. It lives in the forest the tundra the desert
3. It has traits that help it survive without water cold temperatures
4. These traits are called characters fur adaptations
5. Which of the following are adaptations that help the lemming survive in the tundra?

long tail short tail small ears shovel-like claws small eyes white winter fur

TUNDRA PLANTS

1. A wooly lousewort is an insect a bird a plant a mammal
2. It lives in the forest the tundra the desert
3. Tundra plants have traits that help them survive

short winters cold temperatures and wind

4. These traits are called characters cushions adaptations .
5. Which of the following are adaptations that help some tundra plants survive cold?

hair dark flowers small size flowers that turn to face the sun

WHIMBREL

1. A whimbrel is a plant a fish a bird a mammal
2. Whimbrels nest in the north in the south
3. Whimbrels have traits that help them stay cool fly
4. These traits are called camouflage predators adaptations
5. Which of the following are traits that help the whimbrel survive in the tundra?

shovel-like claws migration eggs that match the lichens and plants

INSECTS

1. Most tundra insects survive the winter as adults eggs
2. Many tundra insects have dark light bodies.
3. Some insects make antifreeze gasoline
4. The traits that help tundra insects survive are called characters adaptations
5. Which of the following insects can keep warm because of its fur.

beetle butterfly bumblebee

PTARMIGAN

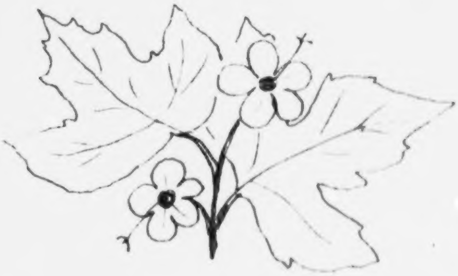
1. Ptarmigan have how many layers of feathers 1 2 3
2. Ptarmigan grow feathers on their feet to keep them warm as snowshoes
3. Ptarmigan turn what color in summer white brown black
4. The traits that help ptarmigan survive are called snowshoes adaptations
5. Which of the following do ptarmigan do in winter?

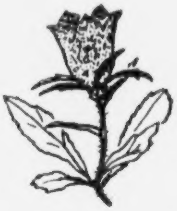
hibernate burrow under the snow

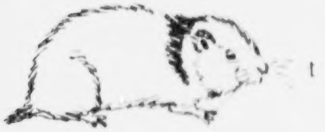
Worksheet 3.
Life on the Tundra

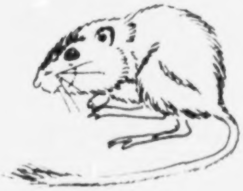
Name____

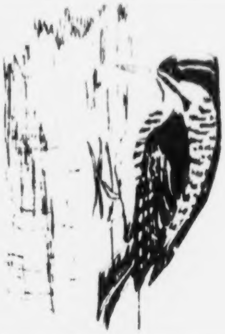
Circle the drawing in each pair that you think shows the plant or animal that is best suited for life in a cold, windy, treeless tundra environment.

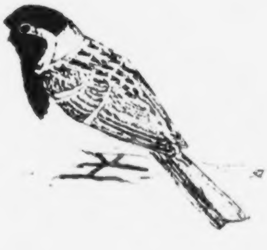


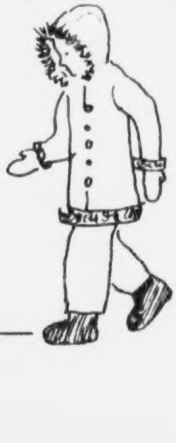


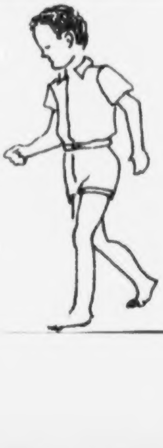












Alaska Wildlife Week Unit 6. © 1988 Alaska Dept. Fish and Game

Lesson 4.

Vocabulary:

food chain, food web, interdependence, symbiosis

Objectives:

Students will be able to describe some of the connections between the non-living environment and living things of tundra ecosystems.

Teacher Background:

Tundra ecosystems, like all others, are made up of all the non-living and living things present and the interactions among these. Tundra ecosystems are sometimes considered simple ecosystems because they are made up of relatively few species of plants, animals, and other living things (as compared to other kinds of ecosystems). Nevertheless, the non-living environment and living things in tundra ecosystems are tied together in complex ways. A summary of important points about the inter-connections within tundra ecosystems is provided below. More details are provided on the following pages.

1. FOOD CHAINS AND WEBS: Energy and minerals are exchanged between the non-living surroundings and living things via food chains and webs. However, the flow of these is considerably less than in other ecosystems because of the short growing season and cold temperatures.

Tundra producers make only one tenth to one third the food made by producers in forest ecosystems each year, and decomposition occurs very slowly. Tundra ecosystems have two important types of food chains, herbivore-based and detritivore-based. Only a small proportion of the food produced each year is consumed by herbivores, which are in turn eaten by carnivores. Instead, most of the material produced dies. Due to slow rates of decomposition, partially decayed material, called detritus, accumulates. The detritus is consumed by certain detritivores, which, in turn, are food for many tundra carnivores. Most detritivores feed on dead material from recently dead plants and animals, but some detritivore-based food chains exchange energy and minerals from peat--the detritus of producers that lived 1,000-12,000 years ago.

2. POPULATION CYCLES: Many populations of tundra animals fluctuate between high and low numbers. Some populations appear to fluctuate in a regular pattern, or cycle. Scientists do not yet understand all the reasons that such fluctuations occur, but plant-herbivore interactions, predator-prey interactions, behavior, genetics, and nutrient (mineral) recycling to the soil may be involved.

3. SYMBIOTIC ASSOCIATIONS: Many living things in tundra ecosystems interact with and depend upon other species in associations called symbioses. Three kinds of symbioses are recognized: mutualism, commensalism, and parasitism. Lichens, pollination, and mycorrhizal associations are examples of mutualistic symbioses--associations from which both interacting species benefit. The dependence of scavenging foxes and ravens on predatory wolves and bears, and the association of nesting birds with species that give predator-alarm calls, are examples of commensalism--symbioses from which one species benefits and the other is unaffected. In parasitic symbioses, one species, the parasite, benefits, while the other, the host, is harmed. The relationship between warbleflies and caribou is an example of parastitism.

4. OTHER CONNECTIONS BETWEEN NON-LIVING AND LIVING SYSTEMS: Some connections between the non-living environment and living things are more easily observed in tundra ecosystems than in perhaps any others. Changes of a few inches in elevation, a few days worth of snow cover, or a few degrees in aspect cause striking differences in the species of plants and other organisms that can survive. In addition, all the variation in environment and living things can occur within a few square meters of tundra. Similarly, the influence of living things on the non-living environment is striking and easily observed. The effects of vegetation on soil temperatures is dramatically revealed by the melting of permafrost and drastic changes in soil that occur whenever plant cover is removed or disturbed. The importance of nutrient recycling is clearly revealed by the lush growth that occurs around owl and jaeger perches, around ground squirrel and arctic fox dens, and around bones and carcasses of dead animals.

TUNDRA FOOD CHAINS AND WEBS:

The non-living things in tundra ecosystems include air, water, soil, rocks, and energy. Energy and minerals (defined as elements and common compounds) make up both non-living and living things. As in all ecosystems, the energy and minerals from the non-living environment move among living things via food chains and webs, then return to the non-living environment. Simply stated, a FOOD CHAIN is the pathway of energy and minerals from the non-living surroundings through producers and consumers and back. A FOOD WEB is made up of all the interconnecting food chains in an ecosystem.

PRODUCERS are those organisms that convert (through photosynthesis) energy from sunlight and minerals from the air, water, and soil into food for other living things. Plants, algae, and lichens are all important producers in tundra ecosystems.

Tundra producers can only function for a few months each year due to lack of light (from darkness and/or snow cover), low light intensity, cold temperatures, and lack of moisture. Thus, tundra producers are like a bottleneck limiting the flow of energy and minerals through the ecosystem. Scientists measure the flow of energy and minerals by determining the weight of carbon that is changed into living material (or fixed) by producers each year. The dry weight of all new growth--leaves, roots, flowers, cells, etc. is used to estimate carbon fixation. On average, all tundra producers together fix only 200 gms of dry weight per year per square meter (range of 100-1000 gm/m2/yr). In comparison, producers in forests fix an average 2000 gms of dry weight per square meter per year (range 1060-3460 gm/m2/yr). In other words, tundra producers make only 1/10-1/3 as much food each year as producers in forest ecosystems. This may be part of the reason that few species of herbivores occur in tundra ecosystems, and why large herbivores (such as caribou and muskoxen) travel over large areas of tundra to find food.

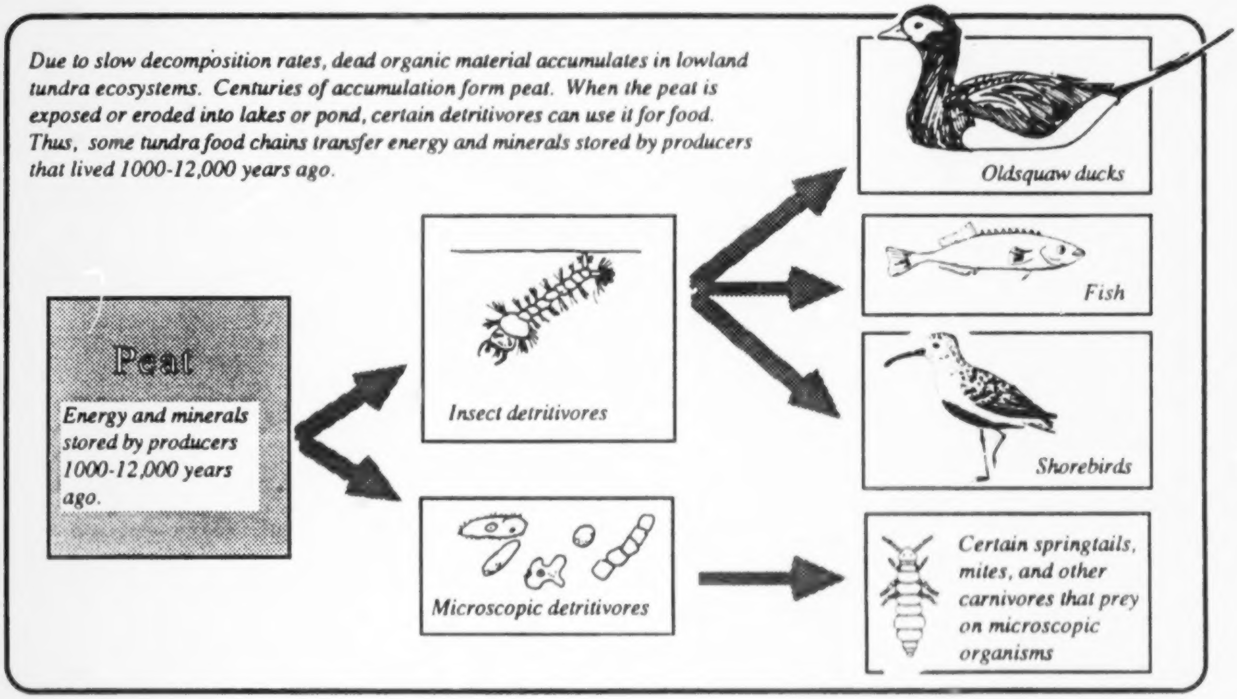
CONSUMERS, those organisms that cannot make their own food, form all the other links in food chains. Consumers are divided into several sub-groups, or trophic levels, based upon the foods they eat; these categories are herbivores, carnivores, and detritivores. Omnivores are consumers that function at 2 or more trophic levels.

HERBIVORES are organisms that eat producers. Lemmings, caribou, and geese are the most noticeable and important herbivores in lowland tundra ecosystems. Voles, pika, marmots, Dall sheep, and mountain goats are the most obvious and important alpine tundra herbivores. Invertebrate animals, particularly insects, are also important herbivores in some tundra environments. Bumblebees, moths, butterflies, aphids, and sawflies are examples of invertebrate herbivores.

Wolves, wolverines, arctic foxes, weasels, jaegers, gyrfalcons, golden eagles, and snowy and short-eared owls are conspicuous and important CARNIVORES of tundra ecosystems. These animals prey on the abundant vertebrate herbivores of tundra. Many kinds of small, insect-eating shorebirds are important carnivores in tundra ecosystems, despite the scarcity of insect herbivores (the reasons for this are discussed below). Relatively few insect-eating invertebrates occur in tundra ecosystems, but some predatory craneflies, spiders, and ground and rove beetles occur.

Most tundra consumers eat a variety of foods depending on what they can find, because food is often scarce. Typical herbivores such as arctic ground squirrels sometimes eat bird eggs, and caribou, which eat mainly plants and lichens, have been observed eating bird eggs and even lemmings. However, some tundra animals function at all 3 trophic levels (herbivore, carnivore, and detritivore.) They are called OMNIVORES. A brown bear is probably the best example of an omnivore; ground squirrels, carrion, and plant roots and berries, and (sometimes) caribou calves are all important parts of their diet in tundra ecosystems.

DETRITIVORES, consumers of dead organisms, are often overlooked, but are extremely important in all ecosystems. Detritivores perform the opposite task of producers by returning minerals and energy locked in dead (formerly living) things to the non-living surroundings. Without detritivores, producers would soon run out of the minerals they need to make food. Important tundra detritivores include: enchytraeid worms, springtails, mites, the larvae of many kinds of flies, nematodes, certain fungi, and microscopic organisms, including bacteria and protozoans.


Due to slow decomposition rates, dead organic material accumulates in lowland tundra ecosystems. Centuries of accumulation form peat. When the peat is exposed or eroded into lakes or pond, certain detritivores can use it for food. Thus, some tundra food chains transfer energy and minerals stored by producers that lived 1000-12,000 years ago.

Peat
Energy and minerals stored by producers 1000-12,000 years ago.
Insect detritivores
Microscopic detritivores
Oldsquaw ducks
Fish
Shorebirds
Certain springtails, mites, and other carnivores that prey on microscopic organisms

Despite the abundance and variety of detritivores in tundra ecosystems, they represent a second bottleneck in the flow of energy and minerals. Most detritivores can only function in the top few inches of tundra soil (the top 2 in (5 cm) in the arctic) and only during a few short months each year because of the cold temperatures and (on some sites) the wet, acidic soils. The weight of all the dead material broken down by tundra detritivores is slightly less than the weight of new material made by producers each year. As a result, dead, partially decayed material, called DETRITUS, slowly accumulates in tundra ecosystems. In alpine tundra, wind and water erosion carry away much of the excess. But in flat areas of lowland tundra, particularly in the arctic, centuries of accumulation have created thick layers of detritus, called peat. A lot of energy and minerals are locked up in this peat layer.

At each link in every food chain, some energy is returned to the environment as heat and is lost to the ecosystem. It can not be reused. Because energy is not recycled, all ecosystems must have a constant resupply of energy from the sun, and this must be continually converted into food by producers. In contrast, minerals are recycled. Those that become part of a producer or consumer are passed along through food chains, until they are returned to the non-living surroundings where they are available for re-use by producers. Because of slow decomposition rates in tundra ecosystems, much of the nitrogen, phosphorus, and calcium that could be reused by producers is insteadtied up in the accumulated detritus and is not available. As a result, the growth and production of many tundra producers is limited by lack of these minerals.

DETRITUS FOOD CHAINS--Despite the low productivity of living producers in tundra ecosystems, a surprising variety of consumers, particularly carnivores, flourish. This occurs because many tundra food chains are based not on living producers, but instead on dead organic material and, in the case of some food chains in tundra ponds and lakes, on peat. Detritivores break down waste materials and return energy and minerals to the non-living surroundings, but some of the food (energy and minerals) they consume is incorporated into their bodies. Many carnivores, including certain insects, ducks, shorebirds, and fish get the energy and minerals they need by feeding on detritivores. The energy and minerals in accumulated organic material thus forms the base of some arctic tundra food chains. Essentially, the consumers in detritivore-based food chains live off energy and minerals stored by tundra producers in past years. The consumers in peat-based food chains are actually supported by producers that lived 1,000 to 12,000 years ago!

SYMBIOSES:

In addition to interacting through food chains and webs, many living things interact with and depend upon each other in other ways. When two kinds of living things "live together" or depend upon one another in some way, their relationship is called a SYMBIOSIS, or symbiotic association.

In some kinds of symbioses, both interacting species benefit from the association. The most striking example of mutualism in tundra ecosystems is provided by lichens. Many people mistakenly think that the lichens which cover much of the ground in many tundra areas are plants. Lichens are actually a combination of two organisms, a fungus and an alga or cyanobacterium, that live in a mutualistic symbiosis. The algae, which are capable of photosynthesis, manufacture food for themselves and the fungi. The fungi provide a protective shell that protects the algae from being dried out by the wind. In some cases the fungi may also help the algae obtain nutrients from rocks, the soil, or rain water by giving off acidic fluids that break down these surfaces.

Another good example of mutualism that is found in tundra ecosystems is pollination. Many tundra plants, like sedges and cotton grass, depend on wind to carry their pollen. Plants that are less common, or can grow only in specific sites on the tundra, must rely on insects to ensure successful exchange of pollen with others of their species. About 90 percent of alpine and over 60 percent of arctic tundra flowers are insect pollinated. (However, most tundra plants have back-up methods of reproduction, so they can survive even without pollination.) Bumblebees are one of the most important pollinators found in tundra ecosystems, but many insects, including butterflies, moths, mosquitos, and other flies are also important pollinators of tundra plants. The pollinators benefit from this association because the plants supply them nectar and pollen for food.

Other examples of mutualism include the connections between berry plants and berry-eating animals that carry their seeds, between nitrogen-fixing bacteria and certain legumes, and between mycorrhizal fungi and certain plants. In the latter two examples, the former organism helps the plant obtain needed minerals, while the plants provide sugars for their symbionts.

The term "commensalism" is used to describe symbiotic associations from which one species benefits, while the other is unaffected. For example, arctic foxes scavenge food from the kills of polar bears, brown bears, and wolves. These larger predators are unaffected--essentially they don't miss the scraps--but the foxes benefit from the food that they could not obtain on their own. Another example of commensalism is the relationship between golden or black-bellied plovers and other smaller shorebirds. Plovers nest on high spots on the tundra--frost boils, pingos, and ridges. Both the male and female plovers guard their nest and are very watchful for possible predators. Plovers give a loud warning whistle to warn their mate on the nest to be alert whenever they spot a predator. Other smaller shorebirds have been found to nest near plovers and to react when the plovers give an alarm call. By nesting near a plover, these birds gain a sharp-eyed guard for their own nests.

In a third type of symbiosis, one species benefits while the other is harmed. One of the most striking examples of parasitism is the relationship between warbleflies and caribou. These parasitic flies lay their eggs on a caribou's coat. When the eggs hatch, the larvae burrow into the caribou's skin and feed on the caribou's body fluids. When the larvae are fully grown, they burrow out and drop to the ground, where they eventually metamorphose into adult warbleflies. The warblefly larvae benefit from the food and shelter provided by the caribou, but the caribou suffer. Caribou under attack by warbleflies spend less time feeding and ruminating, and more time moving to avoid the flies. Severe harrassment by flies may result in caribou entering winter in poor condition, and ultimately reduce their survival and reproductive success. Many kinds of parasites occur in tundra, including fungi and insects that parasitize plant roots and many microscopic organisms that cause animal and plant diseases.

Introductory Activity 4.

Objective:

Students will become aware of the food chain and symbiotic connections among the living things in a tundra ecosystem.

Skills:

SCIENCE: comparing, inferring, predicting
LANGUAGE ARTS: reading, questioning and answering

Materials:

Tundra Connection Cards (see following pages--cut out and laminate), masking tape, 3 colors of yarn, pre-cut in 2, 4, and 6 foot lengths, if desired.

Procedure:

SUMMARY: Students will use information on the Tundra Connection Cards to discover food chains, then to construct a model of a tundra ecosystem that includes food web and symbiotic connections along with connections between living things and the non-living environment. Students will use the model to discover the ripple effects of change in an ecosystem.

1. PREPARATION: Cut out and laminate the Tundra Connection Cards. Select out enough so that each student in the class may have one, and so that all connect into complete food chains. For 30 students, use the 6 sets (of cards) as is. For less than 30, select fewer of the food chains. The carnivore in each set may be removed, or you may add the extra cards to adjust the number of cards up or down for a class number that is not divisible by 5.

2. DISTRIBUTE THE CARDS AND EXPLAIN THE ACTIVITY--THEN TIME STUDENTS. Tape 1 card to each student's knee with side 1 up, and with the card upside down so the student can easily read their own card. (To make this step even simpler for young students, divide the class into groups of 5, or groups equal to the number of cards in each food chain) and distribute a set of cards within each group.) Ask each student to read his/her card. Then, explain that each student must try to find someone else with a card that shows a living or non-living thing that the item on their card needs. They do this by talking to others in the class (or group), and saying I am a -----, I need------ (to eat, or to make food.) If the person they ask is the needed item, the two must join hands and circulate together in search of others they might connect with. Explain that if everyone works together to find the connections, the class should eventually form 6 circles of 5 students each

3. DISCUSS THE CONNECTIONS STUDENTS DISCOVER. Review the connections found in each group with the class. Explain that each of the groups represents a tundra "food chain." Discuss the kinds of things found in each food chain.

Does each food chain include the non-living environment (sun, water, air, and soil)? (Yes.)

Does each include an organism that makes food from non-living things? (Yes.) What are most of these? (Plants, but a lichen is also included.)

Does each food chain include a plant-eating organism--a herbivore? (Yes.) Name these.

Does each food chain include an animal that eats other animals--a carnivore? (Some may not.) Name these.

Does each food chain include an organism that eats dead things--a detritivore (or decomposer). (Yes.) Name these. What do the detritivores do? (Detritvores return minerals from wastes and dead organisms to the soil.)

4. STUDENTS FORM A FOOD WEB. Now, explain that these food chains show just a part of all the connections in a tundra ecosystem. To help students better envision all the connections, the class is going to work together to make a model of a tundra ecosystem.
a) Have all the students with non-living cards stand in a circle in the center.
b) Ask the rest of each group to line up in food chain order next to their non-living player. (The groups should line up so each line projects out from the center circle like the spokes of a wheel.)
c) State that you will need some help, so you are going to have just one student represent the non-living environment. Take the extras aside and ask them to help you. Give all the non-living

cards to the one remaining student. Use lengths of 1 color of yarn to connect all of the students within each food chain group to the non-living environment student. (The extras can help you here.) (Students hold onto the yarn instead of each other's hands.)
d. Have students sit down (in place, still holding on to the string.) Explain that most living things eat more than one kind of food, and belong to more than one food chain. Ask the herbivores to turn over the card on their knee and read the information on the back. Ask each one to tell which other organisms they connect with. Use lengths of the same color yarn to add all these connections. (Again the extras can help make these connections.)
e. Repeat for the carnivores. Explain that the class now represents part of a tundra food web. A food web shows the interconnected food chains in an ecosystem.

5. ADD THE SYMBIOTIC CONNECTIONS TO THE MODEL--This model still doesn't show all the connections in an ecosystem. Other kinds of connections, called symbioses, are also important. Different organisms help each other through symbiotic connections.
a. Give the extra students the cards for moth, sawfly, botfly, and plover.
b. Now ask the producers and detritivores to turn over their cards and read the information. Discuss each of the relationships described, then use a different color yarn to connect each of these organisms to the organism each needs to help it.
c. Add the new cards to the model, by connecting them to show both their food web and symbioses connections.
d. Explain that many other symbiotic associations exist. Discuss the following and add yarn connections between the appropriate students.

1) Mites often hitch rides on the backs of carrion beetles in order to move the long distances between dead animals. (Connect mite and carrion beetle.)

2) Foxes scavenge the scraps left by wolves and wolverines. (Connect fox with wolf and wolverine.)

3) Certain bacteria cause diseases of animals. (Connect the bacteria with the a few animals.)

6. ADD THE REST OF THE CONNECTIONS TO THE NON-LIVING ENVIRONMENT. By this time, students should be fairly entangled by yarn. Explain that the model still doesn't show some very important ecosystem connections. Ask students if any of the organisms they represent could survive without air to breathe. Without water? Without heat from the sun? Without the soil? (They should recognize that all living things depend upon the non-living environment.) Connect each player directly to the non-living environment with a third color of yarn. Now, at last, the class represents a tundra ecosystem and all the connections between the living and non-living parts of it.

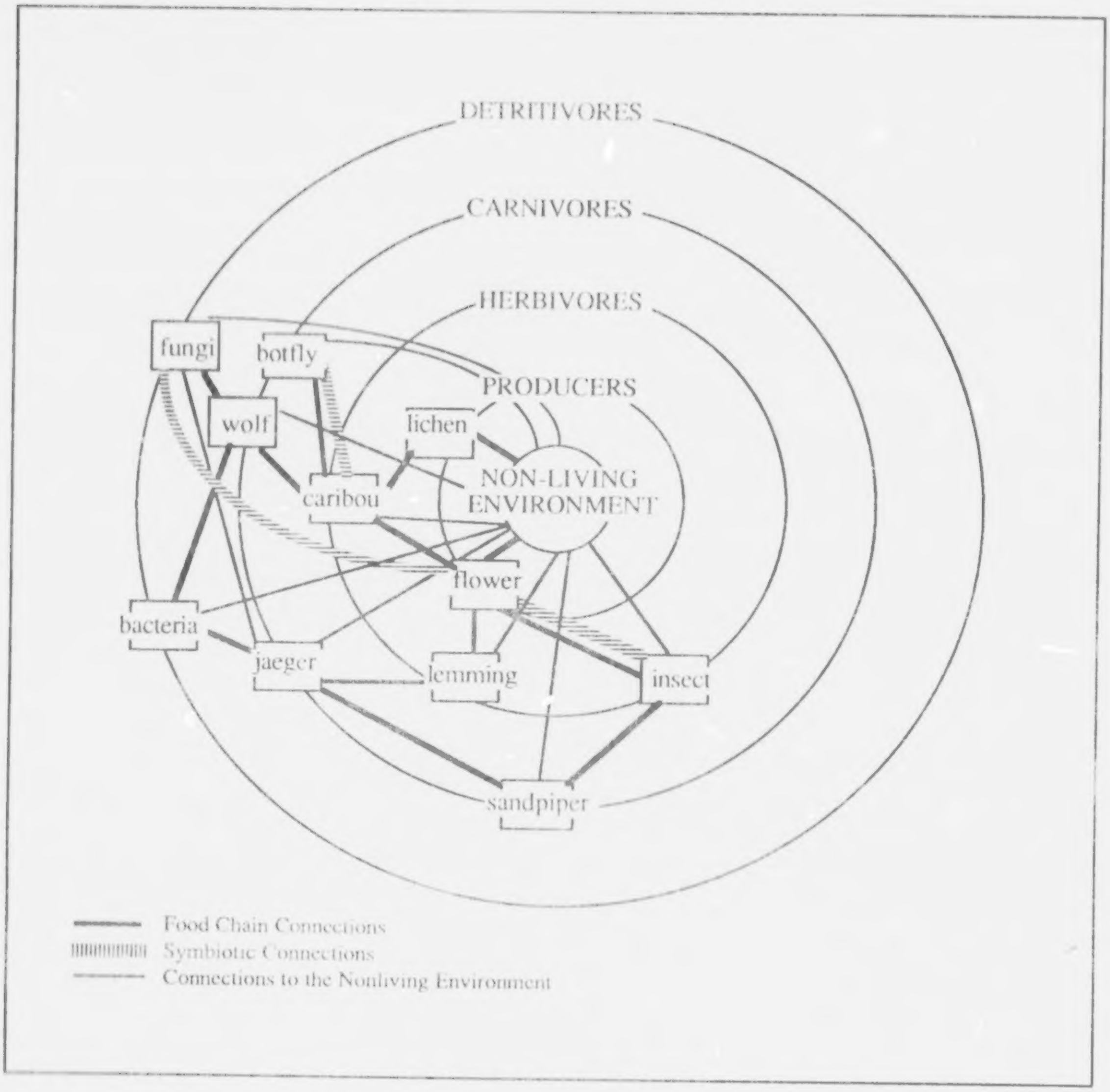
7. FIND OUT WHAT THE CONNECTIONS MEAN--Ask students to think about what all these connections mean. For example, what if the non-living environment changed? (It rained less or more, got warmer or colder, or the air became polluted.) Tell students that they can use their model to find out. Anytime something changes, anything connected to that thing will be affected and change in some way, too.
a. Ask the player representing the non-living environment to stand up to show a change. Any player connected to the non-living environment should then stand up to show that they were affected. What happens? (Everyone stands up--everything is affected.)
b. Illustrate some other changes that might occur. What if all the insects were killed? Have the insects sit down (beetles, midges, sawflies, botflies, and moths). Anyone connected to anything affected must also sit down. Discuss what happened. Repeat for a few single species--what if the lemmings became extinct? Or the willows? Do students understand that any change will result in many other changes?

Extension:

Have students use the Tundra Wildlife Cards to discover more ecosystem connections and make a bulletin board or wall size diagram of all the interconnections they can find. The diagram on page 52 shows a possible format for setting up the display so that it is understandable.

Evaluation:

Have students complete Worksheets 4a and 4b.


DETRITIVORES
CARNIVORES
HERBIVORES
PRODUCERS
NON-LIVING ENVIRONMENT
fungi
botfly
wolf
lichen
caribou
flower
bacteria
jaeger
lemming
insect
sandpiper
Food Chain Connections
Symbiotic Connections
Connections to the Nonliving Environment

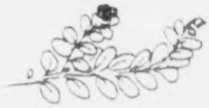
This diagram shows the three kinds of interconnections in an ecosystem. Students may make a similar of more complex diagram using the Tundra Connection Cards, or the Tundra Wildlife CArds.

Tundra Connection Cards

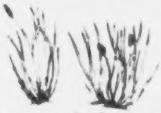
The non-living environment includes sunlight, air, water, and soil. The soil and water contain minerals.

The non-living environment includes sunlight, air, water, and soil. The soil and water contain minerals.

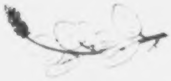
The non-living environment includes sunlight, air, water, and soil. The soil contains minerals.



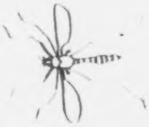
Lingenberries need air, water, and sunlight to make their own food. They also need minerals from the soil.



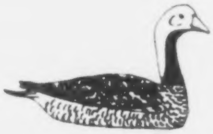
Sedges need air, water, and sunlight to make their own food. They also need minerals from the soil.



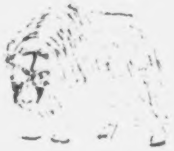
Willows need air, water, and sunlight to make their own food. They also need minerals from the soil.



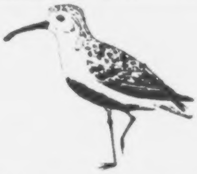
Adult midges feed on nectar from flowers such as lingenberry.



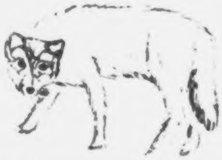
Geese eat sedges.



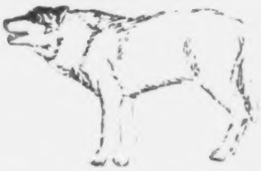
Muskoxen eat willow.



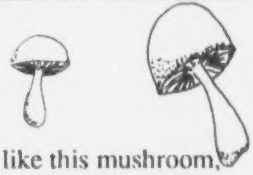
Sandpipers eat insects, including midges.



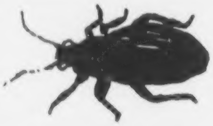
Arctic foxes eat the eggs and goslings of geese.



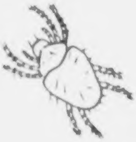
Wolves eat muskoxen.



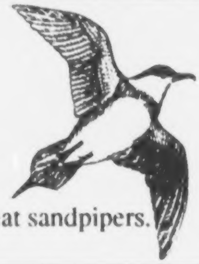
Fungi, like this mushroom, feed on dead animals. They return minerals to the soil.



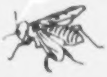
Ground beetles eat dead animals. They return minerals to the soil.



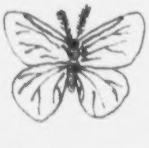
Mites eat dead animals. They return minerals to the soil.



Jaegers eat sandpipers.



Sawflies lay their eggs inside the stems of willows. The willow stem swells to form a gall. The sawfly larvae eat the inside of the gall.



Moths eat flower nectar. They also carry pollen from one flower to another.

The non-living environment includes sunlight, air, water, and soil. The soil contains minerals. 2

The non-living environment includes sunlight, air, water, and soil. The soil and water contain minerals. 2

The non-living environment includes sunlight, air, water, and soil. The soil and water contain minerals. 2

Willows are parasitized by sawflies. These insects cause the willow to form galls or swellings on their stems. The sawfly larvae live inside and feed on the gall. 2

Certain sedges are unable to get enough minerals from the soil. They are food for the organisms that help them. 2

Lingenberries need moths to carry their pollen.They also cannot take enough minerals from the soil. They provide food for the organisms that help them. 2

Muskoxen also eat cottongrass and dwarf birch. 2

Geese also eat lingenberries. 2

Larval midges feed on dead plants. 2

Wolves also eat caribou. 2

Arctic foxes also eat lemmings, sandpipers and their eggs, berries, and beetles. 2

Sandpipers also eat moths, beetles, sawflies, mites, and lingenberries. 2

Mites are not able to move long distances from one dead animal to another. 2

Ground beetles also eat many other kinds of dead animals. 2

Some fungi help plants get minerals from the soil. In exchange, they need food from the plant. 2

Moths eat flower nectar. They also carry pollen from one flower to another. 2

Sawflies lay their eggs inside the stems of willows. The willow stem swells to form a gall. The sawfly larvae eat the inside of the gall and live sheltered from the weather and some predators.. 2

Jaegers also eat lemmings, the eggs of geese, and redpolls. 2

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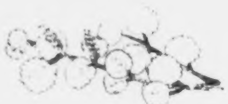
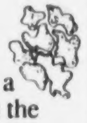
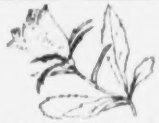
The non-living environment includes sunlight, air, water, and soil. The soil and water contain minerals.



Dwarf birches need certain fungi to help them get minerals from the soil.

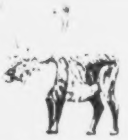


Lichens are really two organisms that live in symbiosis--an algae and a fungi. The algae makes the food, while the fungi keeps the algae from drying out and helps get minerals from rainwater.

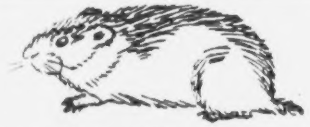


Harebells need moths to carry their pollen.

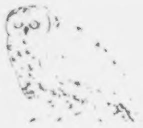
Redpolls also eat the buds and seeds of willows, and herbs like harebell. They also eat insects such as moths, sawflies, and beetles.



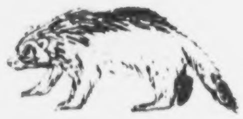
Caribou also feed on cottongrass, willow, and herbs like harebell.



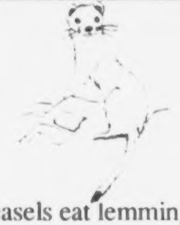
Lemmings eat the shoots of many herbs, including harebell.



Short-eared owls also eat lemmings and sandpipers.

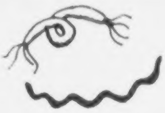


Wolverines also eat lemmings.

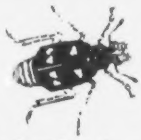


Weasels eat lemmings.

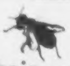
Roundworms also feed on dead plants and animals.



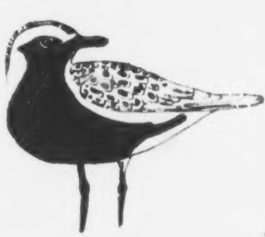
Bacteria also feed on dead plants and animals and the wastes of other animals.

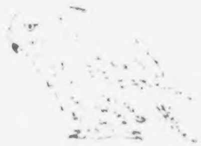


Carrion beetles do not notice if mites ride on their backs as they travel from one dead animal to another.



Botflies lay their eggs on the skins of caribou. The larvae burrow under the skin of the caribou to feed. Later they burrow back out and drop to the ground where they develop into adult botflies.





Snowy owls also eat lemmings.

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The non-living environment includes sunlight, air, water, and soil. The soil and water contain minerals. 2

Harebell flowers make their own food. They needs air, water, sunlight, and minerals from the soil. 2

Lemmings eat the shoots of many herbs, including harebell. 2

Weasels eat lemmings. 2

Carrion beetles feed on dead animals. They return minerals to the soil. 2

The non-living environment includes sunlight, air, water, and soil. The soil and water contain minerals. 2

Lichens need sunlight, air, and water to make their own food. They also need minerals from rain water. 2

Caribou feed on lichens. 2

Wolverines eat caribou calves. 2

Bacteria feed on animal wastes. They return minerals to the soil. 2

The non-living environment includes sunlight, air, water, and soil. The soil and water contain minerals. 2

Dwarf birches need water, air, and sunlight to make their own food. They also need minerals from the soil. 2

Redpolls eat the buds and seeds of dwarf birch. 2

Short-eared owls eat redpolls. 2

Roundworms feed on animal wastes. 2

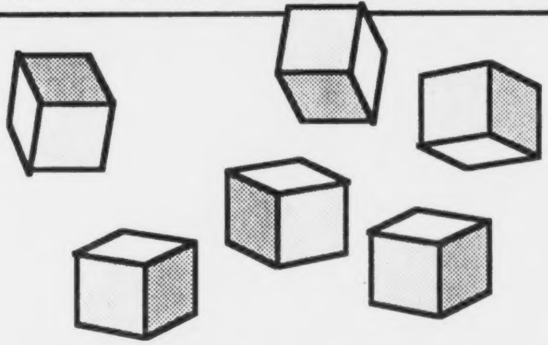
Snowy owls eat weasels. 2

Plovers announce the approach of a fox, weasel, or other predator with a loud whistle. Their whistle warns their mate, and other birds that nest near plovers, such as sandpipers and geese. The warning may help these birds escape the predator or protect their nests. 2

Botflies lay their eggs on the skins of caribou. The larvae burrow under the skin of the caribou to feed. Later they burrow back out and drop to the ground where they develop into adult botflies. 2

Tundra Connection Tumble............ ....MATH / SCIENCE
Groups of 3-5.........Indoors/Outdoors

OBJECTIVES: Students will become more familiar with the living things of tundra ecosystems and practice recognizing food chain and symbiotic connections, while practicing math skills.
SKILLS: Math: counting, addition, subtraction
MATERIALS: Tundra Connections Cards, sides 1 and 2 on separate sheets, or side 1only to simplify the game (duplicate the set from this packet), 6 small square cardboard boxes with all 6 sides, 1 large orange carton or similar sized box without a top, glue, scissors, crayons, pencils and paper for scoring.
PROCEDURE:
1. PREPARATION: This step may be done ahead of time by the instructor or done as a class project. The objective is to color in the pictures from the Tundra Connections Cards then glue the cards on to the small cardboard boxes. You may want to cover the boxes with colorful paper. The cards should be glued on the boxes so that each card from a food chain is shown on a separate box. The remaining Connection Cards (snowy owl, jaeger, botfly, sawfly, plover, and moth) should be pasted on the 6th box. Paste both side 1 and side 2 on a single Connection Card on one side of each box. (Or, to make the game simpler, use only the front of each card.) Once completed, you will have a set of 6 "Tundra Dice."
[NOTE: To have students do this step, divide them into groups and have each group color in one food chain set, plus one of the extra cards. Then have students in each group paste their cards onto separate boxes. Again, only one card from each food chain set should be pasted on any box.]
2. STUDENTS PLAY TUNDRA CONNECTION TUMBLE: This game is intended for small groups of students (3-5). (You can make several sets of the above boxes, if you want to have the class all play at once.) In this game, players roll the "Tundra Dice" (by tossing them out of the large box) and then identify food chain and symbiotic connections among cards on the face-up sides of the dice. Points are awarded for the connections each player finds.
SCORING: The instructor must determine a scoring method based on the math skills of students and those skills he/she wants students to practice. (See three possible scoring methods presented on the following page.) If desired you could make up a score sheet showing all the connections and the answers so students can check their own answers.



ALTERNATE PLAYING METHODS:
A) BABY VERSION: This version is the best for use with first graders. Use Scoring Method 1 or 3. Toss 5 of the dice, then have the beginning player toss in the 6th dice. If using Method 1, he/she gets 1 point for the tossed die plus one for each block that connects with it. If using Method 3, the player gets the points shown on the die, plus the points from any dice that connect with that die. The next player may select any die to toss. He/she scores using the same method as Player 1. In this version, students do not get points for connections between dice unless the connection includes the die they tossed. (A player may still get a food chain of up to 6 connections, however. If he/she tosses a die and the other 5 dice then fit into one long chain, he/she gets points for each connection, or from each of the blocks in the chain.) Toss all the dice after each round.
B) SMALL GROUP--SEMI-ADVANCED VERSION--Each player throws all the dice, finds all existing connections, describes the connections to other players and figures his/her own score. Use any scoring method. Player must state when finished with his/her play. Optional: After a player says he is done with his turn, other players may challenge and earn points by identifying additional connections missed by the player, or pointing out scoring errors. Award 2 points for each error spotted to the player who spots them. Penalize 2 points for any unjustified challenges.
C) CLASSROOM VERSION: This version allows a larger group to play all at once. Use Scoring Method 1, 2, or 3. However, all students need to be able to see the dice. Toss the dice, then have all players find and write down the connections they see and add up their scores. Compare answers to see if everyone found the same connnections and scored the same points. One student reads off the connections he/she found and the points awarded for the connection. Others check off those they have in common. If any student finds a connection others missed, that student earns double the points.

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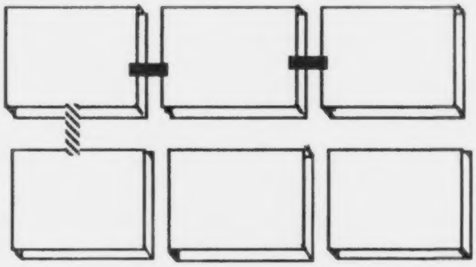
Tundra Connection Tumble--Scoring Methods

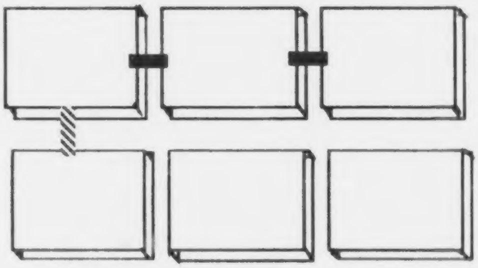
▬ Food Chain Connections
▨ Symbiosis Connections

SCORING METHOD 1. Students earn a) 1 point for each connection, or b) 1 point for each block which they can connect with another (by a food chain or symbiosis connection). Thus, for example, if a student throws the dice and finds a predator and prey (food chain connection), they would get a) 1 point, or b) 2 points. This will give practice counting.



Score a) 3 points--1 for each connection, or b) 4 points--1 for each connected block.

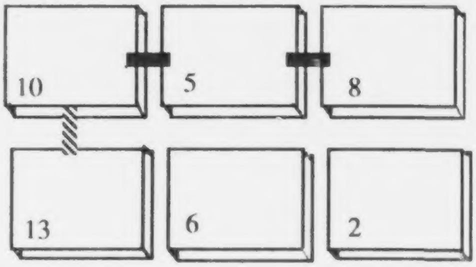
SCORING METHOD 2. In a more complicated version, you might award 5 points for each food chain connection, additional points for partial food chains--i.e., 3 cards that connect in a food chain (non-living, plant, and suitable herbivore) might be worth 12 points, 4--20 points, 5--30, 6--40, and each symbiotic connection-10 points. Write the scoring method out so students can consult it to figure out their scores. Students will get practice adding in this way. For subtraction practice, have students subtract 2 points for each block that doesn't connect to any other.



Score: 12 points (for food chain of 3) plus 10 points (for 1 symbiotic connection) equals 22 points

SCORING METHOD 3. Write a number on each side of each block. Then, students add up the numbers of all the blocks which they can connect together by food chain or symbioses connections, and subtract the numbers on all those that don't connect. This will allow practice with addition and subtraction of 1 to many place numbers, depending on which you write on the sides of the boxes.

Students check each others answers. The player with the most points at the end of the game wins. See scoring examples at right.



Score: (10 + 5 + 8 +13) - (6+2) = 28

Food Chain Mysteries..............SCIENCE / LANGUAGE ARTS
....Indoors/Outdoors

OBJECTIVES: Students will become more familiar with the living things of tundra ecosystems and their food chain interconnections, while practicing language arts skills.
SKILLS: Language Arts: cooperation, dramatic presentation, questioning, reasoning
MATERIALS: Tundra Wildlife Cards, cut out and laminated
PROCEDURE:
1. GROUPS OF STUDENTS MAKE UP FOOD CHAINS: Spread the Tundra Wildlife Cards out on a table at the front of the classroom (or on the ground outdoors). Divide the class into small groups. Ask each group to use the Tundra Wildlife Cards to discover (put together) a tundra food chain. All students have to do is select one animal that interests them, then use the information on the card representing it, to figure out other members of a food chain to which it belongs. (Each card lists what each organism eats, and what eats it.) Remind students that a complete food chain must include the non-living environment, a producer and at least one consumer (a detritivore). It may include up to 4 consumers--a herbivore, 2 carnivores, and a detritivore.) To simplify the game you may want to specify a food chain length--i.e. one of each type of consumer. Allow at least 5 minutes for all the groups to put together a food chain. Each group should write down the names of the organisms in their food chain, in order, then return the cards they selected to the pile.
2. STUDENTS PUT TOGETHER A PLAY THAT ENACTS THEIR FOOD CHAIN. Allow students additional time (about 10 minutes) to figure out how they might want to act out the organisms in their play. Explain that the rest of the class will try to figure out the food chain each group portrays.
3. THE CLASS TRIES TO FIGURE OUT A MYSTERY FOOD CHAIN: Select one group to present their play. The rest of the class should watch the entire play, then try to guess the organisms in the acting group's food chain. The instructor should write correct guesses on the board. [Note: The first link in every chain will be the non-living environment. The next a producer--usually a plant. You may have students try to name the exact plant in the chain, or accept "plant" as an answer (if correct--the producer could be a lichen, algae, or bacteria).] The class may ask the actors yes and no questions about any organisms in the food chain which they don't figure out immediately. For example, they might ask: Does the producer have flowers? Are the flowers purple? Is the detritivore microscopic? The class may also refer to the Tundra Wildlife Cards for help. (For example, if they know the herbivore, but can't figure out the plant, they might look at the herbivore's card and find out what plants it eats.)
5. REPEAT STEP 4 UNTIL ALL GROUPS HAVE PRESENTED THEIR PLAY AND ALL MYSTERY FOOD CHAINS ARE PRESENTED. If you don't have a large enough block of time to do this on a single day, you might spread this activity over the week, and at a certain time each day have one group present their play.

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FOOD CHAIN MOBILES...
INDIVIDUALS / INSIDE...ART / SCIENCE

OBJECTIVES: Students will become more familiar with food chain by making food chain mobiles to decorate the classroom.

SKILLS: Art: cutting, drawing, coloring, design

MATERIALS: sturdy paper plates 1 per student or group of 5, index cards-5 per student or group of 5 students, crayons or felt tip pens of many colors, Tundra Wildlife Cards.

PROCEDURE:

PREPARATION: Read through this entire activity and decide upon the art technique you want students to use, and whether you will have students work individually or in groups of 5 to make their food chain mobiles. Also decide whether or not students can do Step 3. If not, prepare the plate bases for the mobiles ahead of time.

1. STUDENTS FIND A TUNDRA FOOD CHAIN. Have each student (or group of 5 students) use the tundra wildlife cards to develop a tundra food chain that includes the non-living environment, a producer, herbivore, carnivore, and detritivore. Students need only choose one organism that they like, then use the information on the card to find out one thing it eats and one thing that eats it. Then, they need to find a detritivore that feeds on dead animals or plants.

2. STUDENTS USE ART TECHNIQUES TO MAKE PICTURES OF EACH ORGANISM IN THE FOOD CHAIN. After selecting their food chain organisms, students should make a color picture of each organism on a separate index card (5 cards total). These pictures can be drawn using crayons or felt tip pens. Students may cut out their pictures if desired.

VARIATION--Encourage students to make the pictures of the organisms in their food chain using other art techniques. Students could paint, use chalk, or make mosaics using glue and various materials (colored sugars or jimmies, macaroni, hair, feathers, paper pieces, etc.) to make mosaic pictures of each organism.

3.STUDENTS MAKE MOBILE HANGERS:
Have each student do the following, OR make ahead 1 per student or group of 5 students:
  a. Draw a 5-sided star that exactly fits into the plate.
  b. Draw a thick line on the left leg of each star.
  c. Cut along each thick line.
  d. Fold along each right leg of the star.

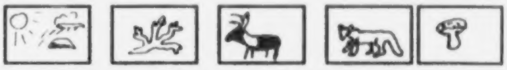
4. Glue (or use string to tie) each picture to one of the mobile vanes. Be sure to place organisms in food chain order: non-living environment, producer, herbivore, carnivore, detritivore.

5. Tie a paper clip (or popscicle stick) at the end of a piece of string or yarn. Punch a small hole in the center of the plate and feed the other end of the string through it. Hang your food chain mobile up!

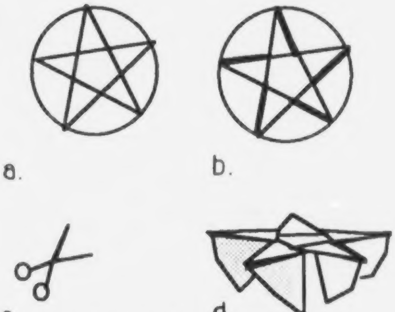
Step 1. Develop a tundra food chain.

non-living environment   lichen   caribou   wolf   fungi

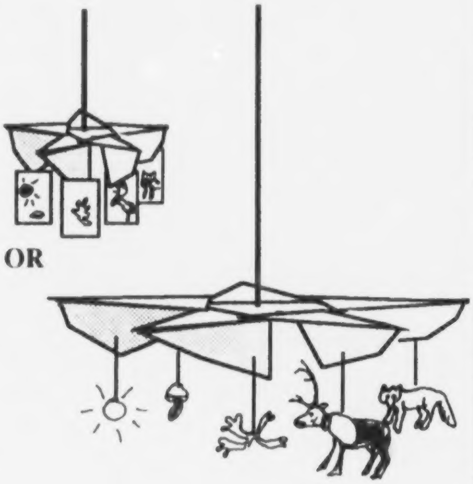
Step 2. Make pictures of each of the items in the food chain.



Step 3. Make the mobile base from a paper plate.



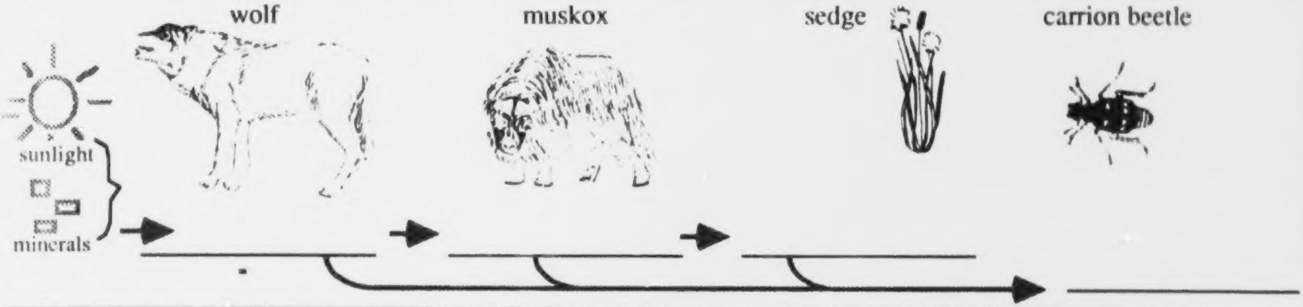
Step 4. Attach the pictures to the base and hang up the mobile.

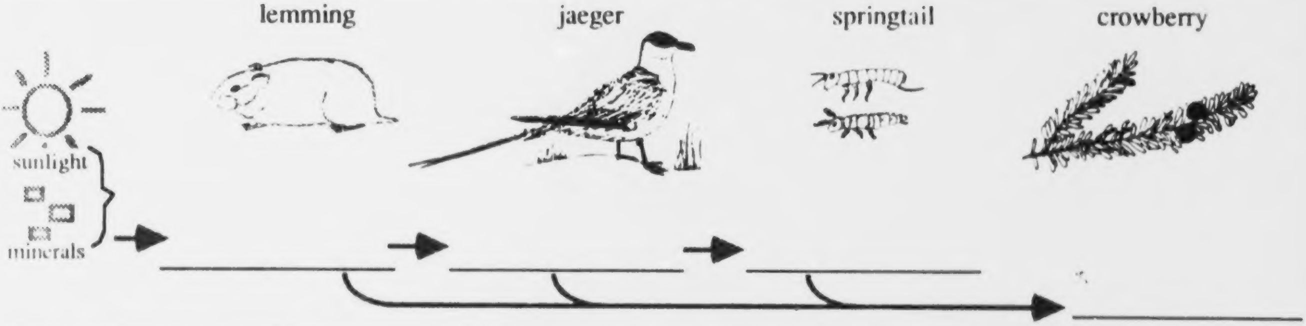


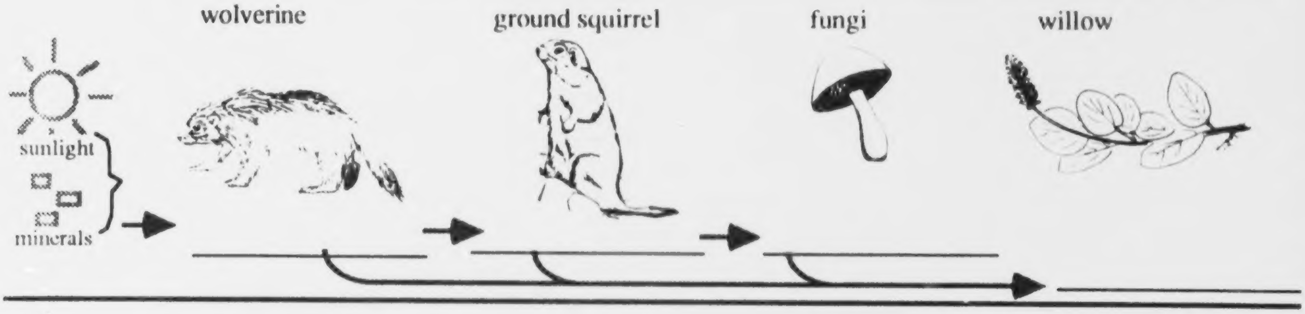
Worksheet 4a.
Tundra
Food Chains

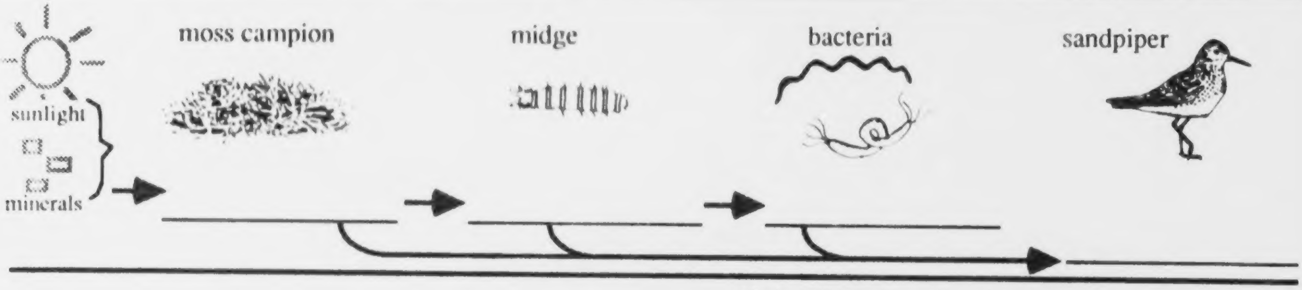
Name______________________________

Each set below shows a group of living things that form a tundra food chain. Look carefully at each set, then draw 1) a circle around the producer, 2) a square around the herbivore, 3) a triangle around the carnivore, and 4) underline the detritivore. Then, 5) write the names of the living things in the order they occur in the food chain.


wolf
muskox
sedge
carrion beetle
sunlight
minerals


lemming
jaeger
springtail
crowberry
sunlight
minerals


wolverine
ground squirrel
fungi
willow
sunlight
minerals


moss campion
midge
bacteria
sandpiper
sunlight
minerals

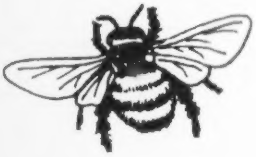
Alaska Wildlife Week Unit 6. © 1988 Alaska Dept. Fish and G

Worksheet 4b.
Tundra Partners

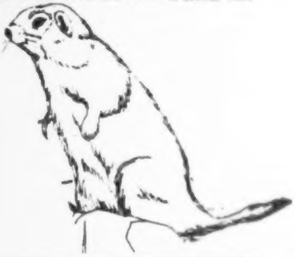
Name_______________________________

Many living things that occur in tundra depend upon one another. Draw a line to connect the living things that could help each other.

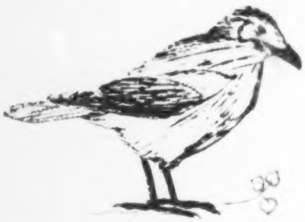
This bumblebee needs nectar and pollen to eat. It can carry pollen from one flower to another.



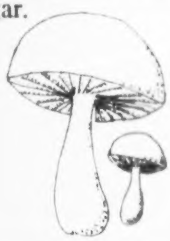
The droppings of this ground squirrel add minerals to the soil around its burrow.



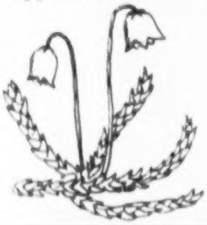
Ravens are scavengers. They feed on scraps left by large predators.



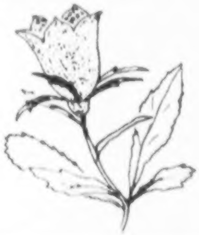
Fungi can take minerals from dead leaves and soil. They need energy in the form of sugar.



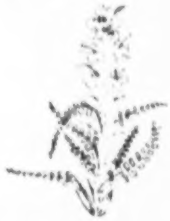
Heather needs another living thing to help it get minerals from the soil. It stores energy from the sun as sugar.



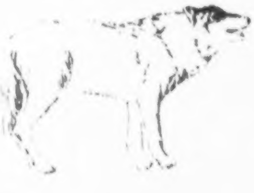
This flower has nectar and pollen. It needs its pollen carried to another flower.



This flower can only grow in soil that is rich in minerals.



Wolves are large predators. They leave scraps around the animals they kill.



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Lesson 5

Vocabulary:

development, fragile, permafrost, productivity, resilient,

Objectives:

Students will recognize some of the problems of use and conservation of tundra wildlife and tundra ecosystems.

Teacher Background:

TUNDRA ECOSYSTEMS: FRAGILE OR RESILIENT? As human populations in tundra regions increase, and as our desires, abilities, and needs to develop resources found in tundra regions increase, humans are changing the tundra. Many scientists are concerned that we may inadvertently, and irreversibly damage tundra ecosystems and wildlife populations. In comparison to most other ecosystems on earth, tundra ecosystems appear relatively simple. Fewer species of plants, animals, and other living things are present, so there are relatively fewer ecological connections. This lack of complexity has led some scientists to conclude that tundra ecosystems are more fragile than other ecosystems, but it has also led other scientists to conclude that tundra ecosystems are more resilient.

Those who consider the tundra to be fragile point out that because there are few interconnections, changes in any single plant or animal population are likely to affect the entire ecosystem. These scientists argue that human activities that affect one tundra species are likely to indirectly affect many other species, just as, for example, natural changes in lemming numbers result in striking changes in populations of foxes, weasels, owls, and jaegers.

Scientists who consider tundra ecosystems more resilient than other ecosystems point to the wide oscillations in animal numbers that occur naturally, the ability of key tundra wildlife, such as lemmings, to reproduce rapidly, and the continued abundance of many tundra birds despite frequent years of nesting failure. These scientists think that since radical changes in animal and plant populations and production occur regularly, tundra ecosystems have a better built-in ability to absorb changes and continue intact than do other ecosystems.

Regardless of tundra's relative fragility or resiliency, however, most scientists agree that we must be cautious in our use and development of tundra resources, because the tundra is different from other ecosystems. Low productivity, the ease of overexploitation of animals, slow decomposition rates, the instability of permafrost ground, and the sensitivity of lichens to air pollution are points which are often raised.

LOW PRODUCTIVITY: As mentioned in previous sections, tundra plants and lichens grow much more slowly than those in other ecosystems, primarily because the growing season is so short, but also due to the low angle of the sun and cool temperatures, both of which affect the rate at which photosynthesis can occur. Most tundra plants of any size are decades or, in some cases, centuries old, and most lichens are also quite old. When plants and lichens are removed by humans, or overgrazed by domestic animals or concentrations of wild animals, decades may be required for plants to become re-established on a site.

Most tundra wildlife also grow and reproduce slowly. For example, brown bears that live on the tundra of the Brook's Range do not breed until they are 8 years old, and then give birth to 2 young only every 4 years. In contrast, brown bears that live in the more productive coastal forests of southcoastal Alaska begin breeding when 4 years old, and have 2-3 young every 3 years. Although certain tundra bird species lay more eggs than related species in milder environments, their overall productivity is lower because they can nest only once each year, complete nesting failures are common, and they likely suffer higher mortality during their long-distance migrations. Some of the large fish found in some tundra ponds and lakes are now known to be 40 years old or more. In contrast, the same kinds of fish in other more productive environments may grow to similar weights in 20 years. Tundra fish such as the

lake trout may reproducing until 10 years old, and then produce fewer eggs than fish in other environments. Populations of animals with slow growth and reproductive rates increase slowly, may decline rapidly if mortality (the number of animals that die) increases, and can only regrow slowly. Small increases in the number of animals that die can thus cause a long-lasting decrease in a population of tundra animals.

Evidence of the vulnerability of tundra wildlife populations is provided by fairly recent declines in certain populations of Alaskan wildlife as a result of overexploitation by humans. Muskoxen were completely extirpated from Alaska during the 1850's, and were it not for surviving populations in Greenland and Canada, the species would have become extinct. The western arctic caribou herd declined from 242,000 in 1970 to less than 75,000 in 1976. The number of wolves living on lands along the Dalton Highway (which parallels the Alaska oil pipeline) was greatly reduced during the 1970's. All of these wildlife population declines are thought to have occurred, at least in part, because too many animals were killed by humans. Humans kill animals for food, furs, sport, protection of life and property, and accidentally (by vehicles on highways, for example). Any population of wildlife will decline if more animals die than are born. Because most tundra animals are slow to mature, and produce few young relative to similar animals in milder environments, the harvest or killing of a relatively small number can cause a population decline (of some species). Tundra wildlife are also more easily overharvested because of the lack of cover--hunters can see them from long distances away.

SLOW DECOMPOSITION: Decomposition, or the breakdown of organic materials, occurs very slowly in tundra environments due to cold temperatures and the short season during which detritivores can be active. Chemical breakdown and weathering of inorganic materials also occur relatively slowly due to the extreme cold and low precipitation of most tundra regions. Consequently, litter and human wastes disposed of in tundra regions remain unchanged for decades and even centuries. Already many tundra areas are littered by disposable diapers, bags of human waste, abandoned oil drums, cans, plastics, and other materials. Unless this material is burned or physically removed by people, it will remain in place, and intact, for centuries.

Accumulated pollutants have more toxic effects than those that are widely dispersed. Because of the slow decomposition rates in tundra environments, air and water-borne pollutants often accumulate. Some tundra organisms, particularly fruticose lichens, are very sensitive to air pollution created by burning fossil fuels. Use of combustion engines in cars, planes, and snowmobiles, and burning of fossil fuels for heat or other uses creates air pollution. Although winds help disperse air pollution in some regions, temperature inversions can result in high concentrations of these pollutants. Additionally, winds may carry pollutants from industrial areas long distances to wilderness areas. Recently, scientists have discovered that some air pollution occurring in Alaskan arctic tundra may have originated in industrial areas of the Soviet Union and Europe.

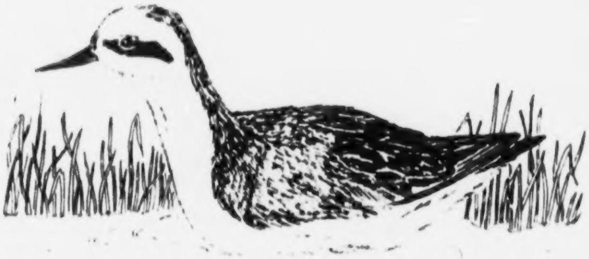
PERMAFROST: Most of the tundra in northern and northwestern Alaska is underlain by permafrost and/or ice. Disturbance or removal of tundra vegetation reduces the vegetative insulation of the soil and results in permafrost melting. When permafrost in wet soil melts, the ground slumps, creating a depression. This depression fills with water during summer. The water absorbs heat from sunlight, which further melts underlying permafrost. In winter, the collectedwater freezes and expands. As it does so, it pushes surrounding soil out and up. Through repeated freezing and thawing and the eroding effects of wind and water the depression grows larger each year. Centuries of accumulation of organic matter may eventually insulate the soil again allowing permafrost to re-develop; only then will the tundra return to its pre-disturbance condition. Because of this long chain of events triggered by disturbance of tundra vegetation, human activities such as driving three-wheelers, snowmobiles, trucks, and particularly larger vehicles over the tundra create very long-lasting and easily visible scars on the land.

In recent years, engineers have prevented melting of tundra permafrost by leaving tundra vegetation intact and piling several feet of gravel on top of it to provide insulation below road surfaces and buildings. This method prevents permafrost from melting, but causes other changes in the tundra. Gravel road beds and building pads are similar to gravel river beds. They are sometimes used by animals that prefer dry tundra. However, few tundra plants can grow on bare gravel, so these pads will remain bare for decades.

These bare gravel sites do not provide the same camouflage or food supplies that natural dry tundra sites do. Additionally, gravel road beds and building pads interfere with the natural flow of water across the tundra. Water usually backs up along the upstream side of the pads. This floods formerly dry or moist sites, melts permafrost, and creates new depressions and ponds, thus changing a much larger area of tundra than the roads or pads themselves cover. Dust that blows off pads and roads also changes snowmelt patterns in surrounding areas. Finally, the huge amounts of gravel needed to build the roads and pads must be excavated from river beds and gravel banks. The extraction of gravel can affect water flow, turbidity, and other physical characteristics of rivers, thus upsetting fish migration and destroying overwintering and spawning habitat of fish. It also removes riparian (streamside) habitat that is important for muskoxen, caribou, ground squirrels, ptarmigan and other birds, as well as other kinds of living things.

VASTNESS AND VULNERABILITY:
To many people the vastness of lowland tundra is part of its beauty and wilderness value. Others feel that because the tundra covers such large areas, human activities do not have a significant impact on the tundra ecosystem. To an extent, both viewpoints are correct. Most tundra wildlife are forced to use large areas to obtain adequate food. The great caribou herds and wolves, their predators, wander over thousands of square miles. Tundra brown bears have home ranges of 100-400 square miles. Even fairly small birds like golden plovers defend territories measured in acres. Consequently, the densities of birds and mammals are low throughout most of the tundra expanses. Thus, even though buildings, airports, roads, and other human constructions may permanently change large areas of tundra and displace tundra wildlife, the actual numbers of animals displaced by individual projects is often small and seemingly insignificant.

Notably, tundra animals are concentrated at certain times and places, and disturbance of these sites may have serious consequences. For example, tens of thousands of caribou concentrate in relatively small areas for calving, and in insect relief areas during mid-summer; thousands of geese concentrate around large tundra lake systems to molt their wing feathers; hundreds of thousands of waterfowl and shorebirds concentrate in productive coastal tundra prior to fall migration; and tens of thousands of snow geese congregate in dry tundra of northern Alaska prior to fall migration.



On the other hand, the productivity of tundra ecosystems is a reflection of their vastness. Herds of 150,000-200,000 caribou could not survive if confined to a small tundra area; they would soon overgraze the lichens and other plants and die from lack of food. Nesting birds space themselves throughout available nesting habitat; those that are unable to find or defend a nesting territory simply do not nest. Hundreds of thousands of geese and ducks, and millions of shorebirds, nest in Alaska's wet lowland tundra expanses, making these among the most important bird nesting grounds in North America.

These impressive numbers reflect the vastness of the tundra more than its productivity. Reductions in the amount of tundra available for nesting will inevitably reduce the numbers and productivity of tundra birds.
Additionally, many nomadic tundra wildlife, such as snowy owls, jaegers, and arctic foxes, require vast areas of tundra because the conditions they need for successful reproduction and winter survival do not continuously occur at any one location. These species continually wander from one tundra region to another in search of suitable food supplies, and their numbers would likely decline if considerable areas of tundra habitat were disturbed or developed.

When we assess the productivity and value of the tundra we often think of the cumulative wealth and productivity of its wide expanses. In assessing human impacts, we must also consider the cumulative impacts of all development projects, recreational use, air pollution, and other human activities. Changes in tundra are long-lasting; areas disturbed 50 years ago have still not returned to their original states. Thus, while individual projects may have relatively little impact, the sum total of many projects conducted over a period of many years (or even decades), could significantly and permanently reduce the wealth of waterfowl, shorebirds, and caribou produced in Alaska's tundra ecosystems.

Introductory Activity 5.

Objective:

Students will recognize that human activities can harm tundra ecosystems and populations of tundra wildlife.

Skills:

Social Studies: awareness that people affect their surroundings

Materials:

Large, open play area, a timer, 1 set of index cards 5 cards for each student in the class, each card should be labeled "Food," masking tape, large pieces of paper labeled "Cover" (one for each student in the class, plus 2-3 extra), 2 rolls of crepe paper, 20 sheets of 11x17 or larger paper or cardboard (paper grocery sacks would work). These larger paper sheets, or cardboard, should each be labeled with one of the following words or phrases: village, airport, garbage dump, gold mine, oil drilling pad, pump station, gravel excavation site, fuel storage tank.

Procedure:

1. PREPARATION: Scatter the "Food" cards on the floor around the large, open play area. Place the "Cover" cards on the floor so that they are distant from each other. Tape the Cover cards to the floor (on all 4 sides).

2. EXPLAIN THE RULES OF THE GAME: Explain to students that the class is going to play a game in which they will represent tundra animals (specify any herbivore or a kind of small bird), and the play area represents the tundra. Students, representing the animals, must find enough food and cover to survive and raise young during each short summer (i.e., round of the game). In order to survive the round, each player must collect 5 food cards, and be standing on a cover card before the timer rings the end of the round. If desired, you may also add carnivore players that must catch 2 prey to survive a round. (Carnivores that do not catch enough prey become prey players the next round.)

2. PLAY A FEW ROUNDS: Have students play a few rounds of the game. Depending upon your students and how well they play, you may wish to vary the length of the time for each round. Set the timer for 2 minutes at first, then lengthen or shorten the time as needed to allow most of the players to survive the summer. Record how many survive the summer. Collect all the food cards and scatter them again after each round.

3. INTRODUCE HUMAN ACTIVITIES: Explain that humans do many things that affect the tundra. For example, they build villages. Ask students how building a village might affect the number of animals on the tundra. Take the piece of cardboard labeled "village" and place it on the floor so that it covers up one of the "Cover" cards or some of the food cards. Explain that the cards covered up are no longer available to animals. (If necessary to prevent cheating, pick up the food cards.) Play another round of the game to see if the number of animals surviving changes--(it shouldn't).

Ask students if they can think of other things people do that change the tundra--help them think of the activities listed on the various cards. As each activity is named, place a sheet with that activity shown on it on the floor over some of the food or cover cards. After adding a few more human activity cards, play another round. The number of surviving animals will now be less.

Continue adding additional human activity cards. Use the rolls of crepe paper to show roads and pipelines. Any card these touch become unusable. Play additional rounds of the game.

Do students understand why fewer animals can survive after the tundra has been greatly changed by humans? Why are the effects more serious when there are many changes in the tundra? How would the changes in the tundra affect people living there? Could they find as many berries to gather or animals to harvest?

5. WRITE A FRIENDS OF THE TUNDRA PLEDGE: Discuss with students the variety of human activites that affect tundra, using the information in the background section. Have students think of ways that the harmful effects of each human activity could be lessened (primarily limiting or preventing certain activities). Discuss the pros and cons of student suggestions. Then, as a group, try to write a pledge for Human Friends of the Tundra, that lists specific actions students could take to help protect the tundra (such as not littering, not driving vehicles across tundra plants, recycling cans, bottles, and other materials, and conserving energy and resources).

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Vehicles and the Tundra........................ ....Social Studies / Science

OBJECTIVES: Students will recognize that vehicle traffic over the tundra damages vegetation and may result in melting of permafrost.
SKILLS: observation, predicting, inferring
MATERIALS: 2 equal sized baking pans, soil, water, freezer, moss and lichens (or several pieces of wool cloth, or bats of cotton to cover the pans), a desk lamp with an incandescent bulb or a window with strong sunlight
PROCEDURE:

Preparation: Mix up some potting soil and water and fill 2 pans with it, then freeze solid. Cover the surface of both pans with a thick layer of mosses and lichens (or cloth or cotton bats).

1. STUDENTS REVIEW THEIR KNOWLEDGE OF THE TUNDRA SOIL. Remind students that most tundra is underlain by permafrost, or perennially frozen soil, and much of the surface is covered by mosses and lichens. Show them the pans of frozen soil with the moss (wool or cotton) covering, and explain that these represent models of the tundra.
2. STUDENTS DISCUSS THE EFFECTS OF VEHICLE TRAFFIC ON THE TUNDRA. Ask students if they have ever looked at a tundra area where a vehicle has been driven. Was there any difference? If students do not know, use questioning techinques to help them realize that heavy vehicles crush and often kill the plants and lichens. Some vehicles also tear up the soil, and leave deep tire tracks. Ask students how this might affect the tundra?
3. STUDENTS OBSERVE THE EFFECTS OF REMOVAL OF THE MOSS LAYER. Remove the moss (wool or cotton) from one of the pans, and explain that the tundra area in that pan represents an area that was driven over by a large vehicle. Place both pans under an incandescent light (or in a warm, sunlit window) and ask students to observe what happens to the tundra "in summer when temperatures warm". (Caution: if left long enough, the frozen soil in both pans will melt. Be sure to have students observe them often and notice when the unprotected frozen soil thaws. Compare the soil in the two pans at that time.) Students should note that the unprotected permafrost melts first. Show students the photos on page 5 of the Tundra Wildlife Cards Supplement to this packet. Have students compare the photos. Besides melting the permafrost and changing the tundra, what other effects might the vehicles have? Have students predict the effects on lemmings, caribou, nesting birds, and plants.

Ask students to think of ways to minimize the damage done by vehicles. (Possible solutions: driving on the tundra allowed only in winter on thick snow, driving on the tundra never allowed; use vehicles with big tires that distribute the weight of the vehicle better; build roads with thick gravel beds that insulate the permafrost and then restrict vehicles to these roads.) If possible, have students go outside and look for evidence of the effects of vehicles on the tundra.

Tundra Posters........... ....Art / Social Studies .... Science

OBJECTIVES: Students will recognize that they and others can do things to help protect and conserve Alaska's tundra.
SKILLS: art, communication
MATERIALS: large paper, paints, crayons, examples of posters
PROCEDURE:

1. STUDENTS EXAMINE AND CRITIQUE POSTERS WITH A MESSAGE. If possible show students a variety of posters that were designed to advertise an event, inform people of a law, or the dangers of a certain activity. Have students discuss what they like or dislike about these, and whether or not they think the posters are effective in communicating their message. Discuss why.
2. STUDENTS MAKE THEIR OWN POSTERS TO ENCOURAGE OTHERS TO PROTECT THE TUNDRA. Explain to students that everyone must help conserve tundra wildlife and protect tundra ecosystems, but many people do not know that human activities can harm the tundra, or what they could do to help. Students can help solve this problem by making posters that explain ways of helping protect the tundra. Have each student make up a slogan and draw a picture for their poster. Their slogan may have two lines. The first line might say "Help Protect the Tundra (or tundra wildlife)." or "Don't Let --a given consequence--(Happen)" The second should describe what action people should take to prevent the consequence. (For example--obey hunting laws; stay on the road; recycle resources; walk, don't drive.)

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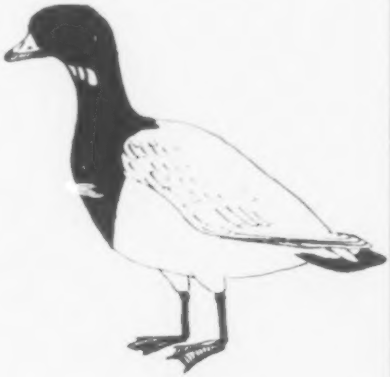
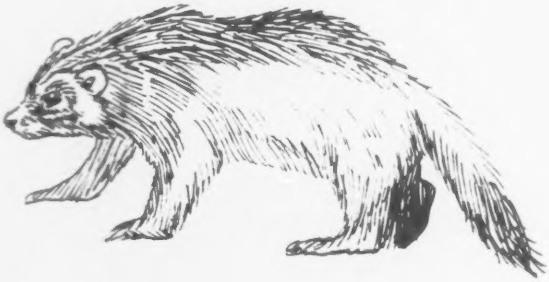
Signs of People............................ ....Art / Science / Social Studies

OBJECTIVES: Students will visit a tundra area and look for evidence of human activities, then compare disturbed and undisturbed sites.
SKILLS: drawing, observation, comparison,
MATERIALS: Pencils, crayons, 11x17 in paper (smaller size is OK), clipboards or cardboard for a writing surface, two similar disturbed and undisturbed tundra sites; these might include a vehicle trail and adjacent tundra that is not used by vehicles; an area with lots of litter, and one with none, or the school playground and a less used area nearby. Be careful not to compare a wet and dry site, or two sites with different aspects or slopes as these will vary due to factors other than human activities.
PROCEDURE:
1. STUDENTS PREPARE THEIR PAPERS. Have each student fold their paper in half, into 8 x 11 inch size. Ask them to label one half, Undisturbed Tundra, and the other side, Disturbed Tundra.
2. STUDENTS VISIT AN UNDISTURBED SITE AND DRAW A PICTURE. Ask students to look carefully at the undisturbed site and draw a picture of it..
a. Guide students through the drawing process by having them first look for all the non-living things in the area, and place these in their picture first. Encourage them to try to match the exact color of the air, water, and soil in their picture.
b. Then ask students to look at the plants in the area. Have them count the number of different kinds of plants they can find in a square yard (or meter). Record this number. Then ask them to add pictures of the most common kinds of plants to their drawing.
c. Repeat step b for fungi, birds, mammals, insects, and other invertebrates.
3. STUDENTS VISIT A DISTURBED SITE AND DRAW A PICTURE OF THIS SITE. Have students turn their papers over to the side that says "Disturbed Site." Follow steps a, b, and c above with students, until they complete their second picture.
4. STUDENTS COMPARE THE NUMBERS AND PICTURES FROM THE TWO SITES. When students have completed the two drawings, return indoors, and have them open up their folded papers to show their two pictures side by side. Discuss the differences, if any, in the color of the air, water, and soil at the two sites. Use the numbers that you recorded to have students make bar graphs of the numbers of kinds of plants, animals, and fungi at each site. Then discuss the differences in these. Ask students which site was more interesting, or had the most variety of living things. Can they explain why?



GEE WHIZ QUIZ.......................... ....LANG. ARTS, PHYS. ED., SCIENCE ....INDOORS / OUTDOORS

OBJECTIVES: The purpose of this game is to review this unit on tundra ecosystems.
MATERIALS: GEE WHIZ TUNDRA QUIZ (next page), large play area for game version 1.
PROCEDURE:
Game Version 1. Divide the class into 2 teams--the wolves and the muskoxen (or any other tundra animals). Mark a home base with a long strip of tape, or rope, at both ends of the room or yard. Assign each team to a home base. Have the teams stand in 2 lines facing each other midway between the 2 home bases. Then explain that the class is going to play a game in which they will use their knowledge of the tundra environment (which they just learned about in this unit), to guess whether or not the statements you make are true or false. If they think your statement is true, the muskoxen are to run toward their home base, and the wolves try to catch them. If the statement is false the wolves should run toward their base, and the muskoxen should try to catch them. Each team earns points for catching members on the other team--as long as they ran the correct (true or false) direction. Reiterate the instructions so that students clearly understand which direction to run. You might want to give some obvious true and obvious false statements as a trial run.



A TUNDRA CELEBRATION

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Celebrate the conclusion of this unit with a Tundra Treat. If you live in an area of tundra, you might try to involve students' families in making dishes from tundra plants and/or animals. If you live in a non-tundra area, you can still make a tundra dish--Cranberry Eskimo Ice Cream. The simplest mixture is to sprinkle berries with sugar, then mash with your fingers or a fork. Stir in canned milk or seal oil (Crisco will do). Wild berries are best, but you can use store-bought ones as an alternative. They are the same species as one of those that grows in tundra and muskegs of Alaska. Salmonberries or blueberries may also be used.

For more traditional recipes that incorporate tundra plants, obtain the reference: Nauriat Niginaqtuat, Plants That We Eat, by Anore Jones, Maniilaq Association

Credit: Idea contributed by Barbara Braley, Badger Road Elementary.

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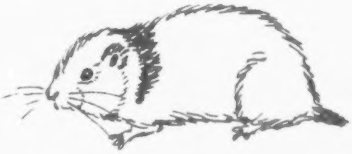
Worksheet 5.

Gee Whiz Tundra Quiz

True or False?

_______1. The tundra is hot.
_______2. Snow helps keep the tundra soil warm during winter.
_______3. Plants make food from sunlight and other non-living things.
_______4. Lemmings have babies during winter.
_______5. Mosquitos are an important part of tundra ecosystems.
_______6. The tundra is a wasteland.
_______7. There are no birds that travel from South America nest in Alaska's tundra.
_______8. On a wet site, the ground may sink if the tundra moss cover is taken away.
_______9. One hundred thousand animals live in every square foot of soil on the tundra surface.
_______10. Alaska's lowland tundra is some of the most important bird nesting habitat in North America.
_______11. A tundra plant has roots that go dozens of feet down into the ground.
_______12. Snow buntings live on the tundra.
_______13. There are no geese that live in lowland tundra.
_______14. Lemmings have long tails.
_______15. Some kinds of fish live in tundra lakes and rivers.
_______16. The tundra is too cold for mushrooms to grow.
_______17. People can not live on the tundra.
_______18. Humans can never harm the tundra.
_______19. Tundra occurs on top of mountains
_______20. Some tundra plants are only 2 inches tall when they are 50 years old.
_______21. Few kinds of living things occur in tundra.
_______22. The tundra is a kind of ecosystem.



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The following references were used in preparing this set of teaching materials. They are listed according to subject to aid those interested in obtaining more information on the topics covered in this unit. Asterisked materials are those likely to be of most use to educators.

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TEACHING ACTIVITIES

Audubon Adventures. Audubon Month 1988 poster and leader's guide. "Alaska Tundra--arctic wilderness." Send $8.00 to Audubon Adventures, National Audubon Society, 613 Riversville Road, Greenwich, Conn. 06831

Alaska Department of Education. Ecosystems of the Great Land--Instructional Videos--Arctic and Alpine Tundra. Available from Alaska State Film Library. Video and teacher's guide.

Alaska Department of Fish and Game--Nongame Wildlife Program, Game Division. Alaska Wildlife Week Educational Packets. (Past units on wetlands, ecology, and wildlife populations contain activities and information relevant to the tundra theme.)

Alaska Sea Grant College Program. Alaska Sea and River Week Curriculum Series. University of Alaska Fairbanks. This excellant set of materials contains many activities useful for studying wet tundra ecosystems. Send for a list of guides and costs.

National Wildlife Federation. National Wildlife Week Education Packet. These materials cover a new theme each year, and include a poster, activities, and stickers. Write: National Wildlife Federation, 1412 Sixteenth Street, N.W., Washington, D. C. 20036

Outdoor Biological Instructional Strategies. Delta Education, Box M, Nashua, N.H. 03061. This excellant set of materials includes 97 activities for outdoor study and discovery. Send for information on costs.

Western Association of Fish and Wildlife Agencies and Western Regional Environmental Education Council. 1983. PROJECT WILD. Excellant activities relating to wildlife and wildlife conservation-national scope. *For information and training contact: Dolores Scott, Alaska Dept. of Fish and Game, Game Division, P.O. Box 3-2000, Juneau, AK 99802*

The following cross-reference of this Alaska Wildlife Week Teacher's Guide and Project Wild was provided by Dolores Scott

AWW	Project Wild
Lesson 1	Habitat Lap Sit - using tundra components
Lesson 2	Forest In A Jar - adding steps with freezing the jar with seeds or exposing it to wind
Lesson 3	Surprise Terrarium
	Rainfall and the Forest - use temp. instead of rain
	Adaptation Artistry
	Tracks
	The Thicket Game
Lesson 4	Interdependence
	Good Buddies - use arctic animal example
	Owl Pellets
	Muskox Maneuvers
	Oh, Deer (using geese or caribou)
	How Many Bears Can Live In This Forest - use tundra instead
Lesson 5	Planting Animals
	Who Lives Here
	Here Today, Gone Tomorrow
	Litter We Know

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Alaska's Living Tundra

Upper Elementary
Teacher's Guide

Alaska Wildlife Week *25-29 April 1988* **Unit 6**

Alaska Department of Fish and Game--Nongame Wildlife Program--Game Division

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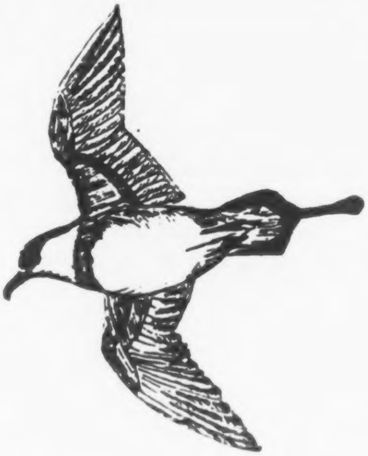
Alaska Wildlife Week 1988
Unit 6. Alaska's Living Tundra



Educational Packet:
Teacher's Guide
Wildlife Photo Poster
Tundra Wildlife Cards
Alpine and Lowland Tundra Posters

Published by: Alaska Department of Fish and Game
Game Division--Nongame Wildlife Program

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Introduction

Imagine a wetland that is really a desert. A place where animals find warmth on hills of ice. Imagine a place where 100 year-old plants are only a few inches tall. A place where billions of insects, millions of birds, and hundreds of thousands of mammals swarm, but where visitors often see nothing. Imagine an environment of contrasts. Imagine Alaska's tundra.

Many people think tundra is cold, barren, and desolate. Perhaps at first glance it is. On closer investigation, however, one finds that tundra environments are among the most fascinating in the world, and that a surprising variety of wildlife not only survive in tundra environments, but also flourish.

Discover this environment with your students as you use this **1988 Alaska Wildlife Week Educational Packet.** This comprehensive unit on **Alaska's Living Tundra** includes: A **Teacher's Guide**--full of background information on Alaska's alpine and lowland tundra environments, interdisciplinary activities, games, and worksheets; **A Wildlife Poster**--with color photographs of 12 species of tundra wildlife and two types of tundra; a set of **Tundra Wildlife Cards**--illustrations of and text about over 100 kinds of organisms that live in tundra environments; and **Tundra Posters** depicting many of the wildlife of Alaska's alpine and lowland tundra.

The Teacher's Guides are organized so that each of the 5 lessons on tundra builds upon those previous. An introductory activity is suggested for each lesson; use these along with any of the the wide variety of Activities for Curriculum Integration that are provided. The thematic approach of the packet is intended to help instructors integrate the study of tundra with regular classroom curriculums. All the activities are designed to help students develop or improve their skills and knowledge in science, social studies, language arts, math, and/or art. Easy-to-duplicate worksheets may be used to review, reinforce, or evaluate student understanding of the lessons in this unit.

Please feel free to adapt and modify activities and worksheets to best suit your teaching style, students' learning styles, and your location and situation. Three separate Teacher's Guides were prepared--one each for Primary (K-3), Upper Elementary (4-6), and Junior/Senior High School. Check to be sure you have the one that best matches your students' knowledge and thinking skills.

As always, we encourage you to integrate Alaska Wildlife Week with other conservation education materials available in Alaska. The Reference List at the end of this guide provides a list of many teaching materials relevant to this unit on Alaska's tundra. (This year, a special cross-reference to the Project Wild materials is included since many Alaskan teachers are also using those materials. See the information provided in the Reference List.)

The Alaska Department of Fish and Game began producing the Alaska Wildlife Week materials in response to teacher requests for Alaska-specific materials on wildlife and conservation. This project was orignally patterned after the National Wildlife Week educational effort sponsored by the National Wildlife Federation. **1988 marks the sixth year of Alaska Wildlife Week.** The theme for this annual celebration has changed each year, and a separate packet on each of six themes have been developed. You will find that the packets developed in previous years have some information and activities relevant to this year's topic. Check your school library for copies.

We hope you will use these materials during Alaska Wildlife Week in 1988, as well as throughout this and other years. Please send any comments or suggestions about this project to: Alaska Wildlife Week, Alaska Dept. of Fish and Game, Nongame Wildlife Program, 1300 College Road, Fairbanks, AK 99708

ALASKA WILDLIFE WEEK.

Upper Elementary Teacher's Guide

UNIT 6. Alaska's Living Tundra

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Lesson / Objective	Teacher Background	Introductory Activity	Ideas for Curriculum Integration	Student Worksheet
1. TUNDRA ENVIRONMENTS Students will learn what tundra is and why it exists only in certain areas.	7-10	11-17	18-21	22-23
2. THE LIVING TUNDRA Students will identify different types of tundra and the organisms present.	24-25	26	27-32	33-34
3. ADAPTATIONS OF TUNDRA LIFE Students will learn about the special traits organisms have to survive in tundra areas.	35-43	44	45-54	55
4. TUNDRA CONNECTIONS Students will learn about the ways the tundra ecosystem is interconnected.	56-60	61-66	67-71	72-73
5. HUMAN USE OF THE TUNDRA Students will recognize that humans can affect the tundra.	74-76	77-79	80-86	87

Supplementary Materials That Accompany This Teacher's Guide

A Color Poster

Color photographs of Alaska'a lowaind and alpine tundra and 12 kinds of tundra wildlife

Tundra Wildlife Cards

Over 100 illustrated cards of common tundra wildlife of Alaska, including birds, mammals, insects, invertebrates, fungi, plants, and microscopic organisms.

Adaptation Cards

Thirty-two illustrated cards with information about animals and their adaptations to various environments.

Alpine and Lowland Tundra Posters

Two pen and ink illustrated posters depicting alpine and lowland tundra environments and wildlife.

Worksheet Answers

Worksheet 1a. The following words are hidden in the puzzle: air, Alaska, alpine, arctic fox, butterfly, caribou, cold, dry, far north, flower, goose, high elevations, high latitudes, jaeger, lemming, long winters, migrants, mosquito, muskoxen, northern, permafrost, pingo, polygon, sandpiper, short summers, snow bunting, soil, sunlight, treeless, water, weasel, wetland, windy. See page 6 for the solution.

Worksheet 1b. Self-explanatory

Worksheet 2a. 1-F, 2-G, 3-D, 4-E, 5-A, 6-T, 7-R, 8-V, 9-S, 10-U, 11-B, 12-O, 13-N, 14-W-(pika), 15-I (King eider), 16-L (caribou).
Secret phrase: A good observer of tundra wildlife.

Worksheet 2b. As latitude increases, the elevation at which treeline occurs decreases. In other words, alpine tundra occurs at lower elevations at high latitudes. A 10 degree increase in latitude results in an approximate 100 feet drop in the elevation of treeline. The southern edge of lowland tundra is actually not defined by a certain latitude, but rather by a combination of latitude and local climate. However, for the purposes of this worksheet, students should have predicted between 65 and 70° latitude.

Reading Comprehension Worksheet:
Lemming: 1. mammal, 2. tundra, 3. cold temperatures, 4. adaptations, 5. short tail, long fur, small ears, shovel-like claws, white winter fur, 6. white
Moss Campion: 1. plant, 2. cold temperatures and wind, 3. adaptations, 4. purple flowers, cushion shape, small size, 5. yes, 6. 2 years; Whimbrel: 1. bird, 2. in the north, 3. fly and avoid predators, 4. adaptations, 5. migration, eggs that match the lichens and plants, chicks that grow quickly; Insects: 1. many, 2. eggs, 3. affected by the surroundings, 4. adaptations, 5. fur, dark colored bodies, small size, antifreeze; 6. yes

Worksheet 3a. 1-n, 2-a, 3-d, 4-o, 5-p,6-i, 7-s, 8-t The secret word is "adaptations."

Worksheet 3b. 1-j, 2-i, 3-h, 4-g, 5-f, 6-e, 7-d, 8-c, 9-b, 10-a.

Worksheet 4a. Alpine Connections: Producers: (green) cranberry, flowering plants, grass; Herbivores (yellow): Dall sheep, tundra voles, butterfly, marmot, pika; Carnivores (red) wolves, jaegers, sandpipers, weasels; Omnivores (blue) brown bear, horned lark; Detritivores (purple) carrion beetles, mites, fungus, bacteria. The following symbiotic connections should be noted: mites-carrion beetles, butterfly--flower, cranberry-fungus, flowering plant-fungus.

Worksheet 4b. Tundra connections: Producers (green) sedges, crowberry, flowering plants, algae; Herbivores (yellow) caribou, emperor geese, lemmings, butterfly, adult, male mosquitoes; Carnivores (red) wolves, jaegers, arctic loons, phalaropes, blackfish, plovers, arctic foxes; Omnivores (blue) brown bears; Detritivores (purple) craneflies, mosquito larvae, bacteria. The following symbiotic associations should be noted: male mosquitoes with all mammals and birds (parasitism), fungi-flowering plants, butterfly-flowering plants and crowberry, algae-fungi (to form lichen), plovers and phalarope, arctic fox--brown bear (also, arctic fox--wolves--award extra points for finding this), geese, lemmings and plovers may spread crowberry seeds--award extra points for finding any of these.

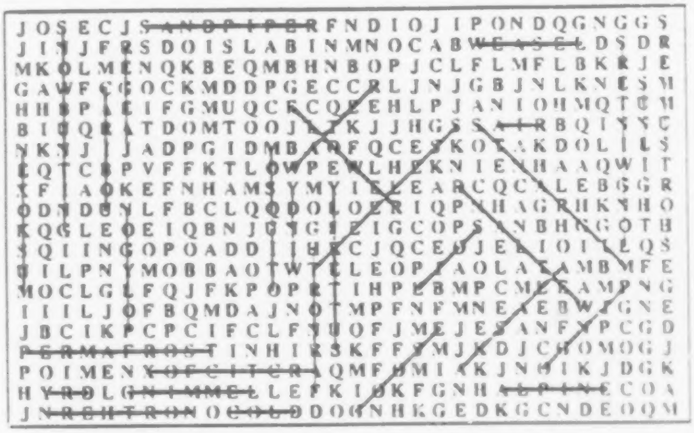
Worksheet 5. Gee Whiz Quiz: 1. F, 2. T, 3. T, 4. F (they are related to rabbits and hares), 5. T, 6. F (only in alpine), 7. T, 8. T (they are food for many other living things), 9. F (it may take decades), 10. F, 11. T, 12. F (thousands do), 13. T (due to permafrost melting), 14. T, 15. F (most need mycorrhizal fungi to help them obtain minerals from the soil), 16. F (they can keep warm better than other insects), 17. T, 18. F (several invertebrate animals can survive freezing), 19. T, 20. T (it also helps keep it cool by reflecting sunlight, however), 21. T, 22. F, 23. T, 24. T, 25. F (they extend horizontally, but are prevented from going vertically by permafrost), 26. T (some areas receive less precipitation than the Sahara Desert), 27. T (even in very dry areas; permafrost prevents water from seeping into the soil, so all the precipitation collects on the surface), 28. T (some crustose lichens are thousands of years old), 29. F, 30. F (it takes years), 31. T, 32. T, 33. F (several kinds nest there), 34. F, 35. T, 36. F, 37. F (it is a symbiotic association between an algae and a fungi), 38. F, 39. F, 40. T, 41. T.

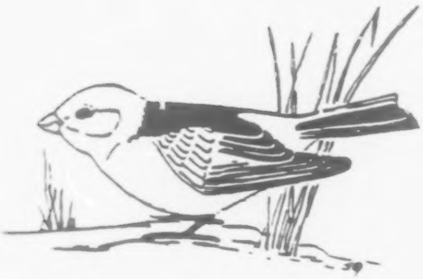
A Tundra Glossary

active layer	the layer of soil, lying on top of permafrost, that thaws and re-freezes each year
adaptation	a trait that enables an organism to survive in a particular environment
alpine tundra	periodically cold, treeless environments that occur at high elevations throughout the world
animal	living things in the Kingdom Animalia; one of the 5 major groups of living things that includes invertebrates (insects, crustaceans, worms, echinoderms, etc.) and vertebrates (birds, mammals, fish, amphibians and reptiles) Animals have a highly organized cell structure; most move from place to place, and all are consumers.
antifreeze	a compound that lowers the temperature at which water, or another liquid (such as sap, cell fluids, or blood) freezes
carnivore	a consumer that mainly eats other consumers; "carnivore" literally means meat-eater, and is usually applied to animals such as wolves, but organisms that eat mainly insects are also carnivores, since insects are consumers.
commensalism	an interaction between two species from which one species benefits and the other is unaffected
consumer	any living thing that gets energy and minerals by eating (consuming) other living or dead things
decomposer	an organism that breaks down dead organic material, thus returning minerals to the non-living environment (includes some micro-organisms that break down dead material without consuming it.)
detritivore	any consumer that ingests wastes and/or the remains of living things that have died; detritivores are a type of decomposer
dormancy	a period of inactivity, in which some or all life processes slow down or stop
ecosystem	all the non-living and living things and their interactions in a specific area
elevation	the height of the ground above sea level
energy	the force that causes objects to move; energy occurs in several forms including in light, heat, and stored in chemical bonds
environment	all the non-living and living things in a particular place
food chain	the pathway of energy and minerals from the non-living environment through producers and consumers back to the non-living environment
food web	all the inter-connected food chains within a particular ecosystem
frost boil	an area of bare soil up to several yards (meters) in diameter caused by repeated freezing and thawing of soil
fungi	one of the 5 major groups of living things. Most fungi do not move around, but instead, live their lives in one place. Most obtain minerals and energy from dead things and waste materials, but some obtain food through symbioses with plants or microscopic organisms. This group includes mushrooms, toadstools, shelf fungi, molds, yeasts, and rusts. (Slime molds are sometimes classified as fungi also.)

herbivore	a living thing that feeds on producers, such as plants, algae, or lichens
hibernation	a period of inactivity, in some mammals, during which all life processes (breathing, heart rate, body temperature, etc.) are reduced; an adaptation to avoid periods of cold and scarce food.
ice wedge	a wedge-shaped lens of pure ice in permafrost soil, caused by a crack in the permafrost that accumulates meltwater during summer; as the accumulated water freezes, an ice wedge grows. Ice wedges are the cause of polygonal ground in lowland tundra
insulation	anything that reduces the movement of heat energy into or out of a particular object or area
irruption	a sudden, large increase in the population density of a particular species in a given area
latitude	a measure of the distance of a given point on earth from the equator
life cycle	the birth, growth, reproduction, and death of a particular kind of living thing
living things	something that is able to move, grow, and make new things like itself; an organism. LIving things are classified into 5 major groups: animals, plants, fungi, monerans and protists.
lowland tundra	the cold, treeless environment found in the arctic and maritime subarctic
migration	a regular, seasonal movement of an animal from one place on earth to another
moneran	one of the 5 major groups of living things; includes only microscopic organisms, including bacteria and cyanobacteria (formerlly called blue-green algae). The cells of monerans do not have a nucleus.
mutualism	an interaction between two species from which both benefit; a type of symbioses
non-living	Something that does not, and cannot, move, grow, or make new things like itself; air, water, soil and rocks, and energy are the non-living things found in all ecosystems
parasitism	an interaction between two species from which one, the parasite, benefits, and the other, the host, is harmed; a type of symbiosis
omnivore	a consumer that eats both producers and other consumers
permafrost	perennially frozen ground that may or may not contain ice. In the arctic tundra permafrost may extend 2,240 feet (700 m) below the surface
pingo	an ice-filled hill on the tundra, sometimes 230 feet (70 m) or more high and 2000 feet (600 m) in diameter; a pingo may be circular, oval, or irregular in form
plants	One of the 5 major groups of living things; includes mosses, ferns, horsetails, conifers and flowering plants; this group is characterized by having cell nuclei and cell walls, a highly organized arrangement of cells, most can do photosynthesis and are important producers; most are green, and all except mosses and liverworts have a specialized system for transport of water and minerals, including roots, stems, and leaves.

polygons	one of the forms of patterned ground characteristic of soil subject to intensive frost action; many polygons are formed by ice wedges; polygons with sunken edges are called high center polygons; those with raised edges and a sunken center are called low center polygons
population	all the animals of a particular species that live in a particular area and interbreed
producer	any living thing that can convert non-living materials (air, water, and light) into food for itself and other living things; plants and algae are examples of producers
productivity	the amount of new growth, or number of young, produced per year or other unit of time
protists	any living thing in the Kingdom Protista, one of the 5 major groups of living things that includes some microscopic living things (algae and protozoans) and kelp or seaweeds; organisms in this group are characterized by their cell structure, which includes a cell nucleus, and by the lack of cell specialization for specific purposes
symbiosis	an interaction between two species in which at least one species depends upon the other
tundra	the windy, treeless, and periodically cold environments that occur at high latitudes and at high elevations
tussock	a small mound formed by certain tundra grasses that continually retain their dead leaves; walking is difficult across tussock tundra; tussocks are used by many kinds of insects and other tundra wildlife





Lesson 1.

Objectives:

Students will be able to describe the main characteristics of tundra environments: the absence of trees, long cold winters and short cool summers. They will be able to explain why tundra occurs at high elevations and northern latitudes.

Teacher Background:

WHAT IS TUNDRA?

The word"tundra" is derived from a Finnish word "tunturi" which means completely treeless heights. The absence of trees is an important characteristic of tundra, but deserts, prairies, and most wetlands are also treeless. The term "tundra" is used to describe the treeless ecosystems that develop in areas with long, cold winters and short, generally cool summers. Permanently frozen ground (permafrost), low precipitation, and persistent winds are important features of some, but not all, tundra environments.

Many people associate the term "tundra" with flat, featureless landscapes. But flatness is not a characteristic of tundra. Tundra occurs on flat plains, on rolling hills, and on precipitous mountain slopes just as do forests, deserts, and prairies. Additionally, many of the tundra areas that appear flat at first glance have surprisingly textured surfaces.

WHERE DOES TUNDRA OCCUR?

Periodic cold temperatures, and thus tundra environments, occur at high latitudes (near the north and south poles of the earth) and at high elevations throughout the world. Most of the tundra on earth occurs in the northern hemisphere because at high southern latitudes, the earth's surface is mainly covered by ocean.

Vocabulary:

alpine, atmosphere, climate, elevation, environment, energy, latitude, permafrost, temperature, tundra

WHY ARE THESE REGIONS COLD?

High Latitudes. Sites near the poles of the earth are cold because they receive less light and heat energy from the sun than do other areas of the earth. This occurs for two reasons. First, the earth tilts 23 1/2° on its axis, and so, in its annual rotation around the sun, each pole alternately tilts toward and away from this primary source of heat and light energy. Lands at northern and southern latitudes have days and nights of unequal length during most of the year. In June, the north pole is tilted toward the sun, so our days are long and nights are short. In December, the north pole is tilted away from the sun, so our nights are long, and days are short. Lands above the arctic and antarctic circles receive no sunlight during 2 months of winter, and little during the entire 6 months when the north pole is tilted away from the sun. In contrast, sites nearer the equator receive constant amounts of sunlight year round (day and night are of equal lengths).

Secondly, at high latitudes, even during the sunlit portion of the year, the sun is low on the horizon rather than overhead. The sunlight that reaches the earth's surface travels through more atmosphere and is spread over a larger area than at more southern latitudes. It therefore delivers less heat and light per unit area per hour.

At high latitudes, winters are long and cold, and summers are cool because of the seasonal tilt away from the sun of each pole, in combination with the low angle of the sun above the horizon during sunlit seasons. At Barrow, Alaska average daily temperatures drop below freezing in September, and remain so until May. From December through March, the temperatures ranges from -20° F (-28° C) to -16° F (-26° C) . At this high latitude site, the sun drops completely below the horizon on 18 November and does not rise again until 24 January.

High Elevations: Cold temperatures occur at high elevations for a different reason. At high elevations, the atmosphere is thin and contains little moisture, so little sunlight is reflected by particles in the air, and much more light and heat energy reach the ground than at low elevations. At first glance, then, it may seem surprising that cold temperatures, and thus tundra environments, occur at high elevations at all latitudes--even at the equator. The reason for this is that carbon dioxide and water vapor in the atmosphere act like a

blanket of insulation around the earth--by reflecting back, or trapping, heat energy. At low elevations, a thick, dense blanket of moist air traps much of the heat that reaches the ground. But at high elevations, the thin air over the mountaintops traps little heat, and provides little insulation fromthe -50°F (-45.5°C) temperature of the upper atmosphere. High elevation sites may have warm temperatures during the day when the sun is shining, but most of the heat is quickly lost when the sun goes down at night. On high mountains, night-time air temperatures are often 54° F (30°C) colder than those at mid-day. Average air temperatures drop 3° F (-1.7°C) for every 1000 feet (305 m) increase in elevation. Thus, when the air temperature is 32° F (0°C) at the base of Mt. McKinley, the temperature on top (20,000 feet) is 60° F colder, or -28° F (-34°C).

WHY IS THE TERM "PERIODIC" IMPORTANT: If the severe cold of northern winters and alpine nights was continuous, living things could not survive. The change from cold, nearly unlivable conditions to cool, milder ones more suitable for living things is thus an important characteristic of tundra environments. The periodic change from severe cold to milder conditions occurs seasonally (winter to summer) in most tundra environments. As one moves closer to the poles of earth, the mild season becomes shorter, and so does the number of kinds of living things that can survive. In high elevation tundra environments near the equator there is no seasonal change in temperatures, but warm (even hot) temperatures occur every day, while bitter cold occurs each night. Thus the term "periodic cold" applies to these environments, too.

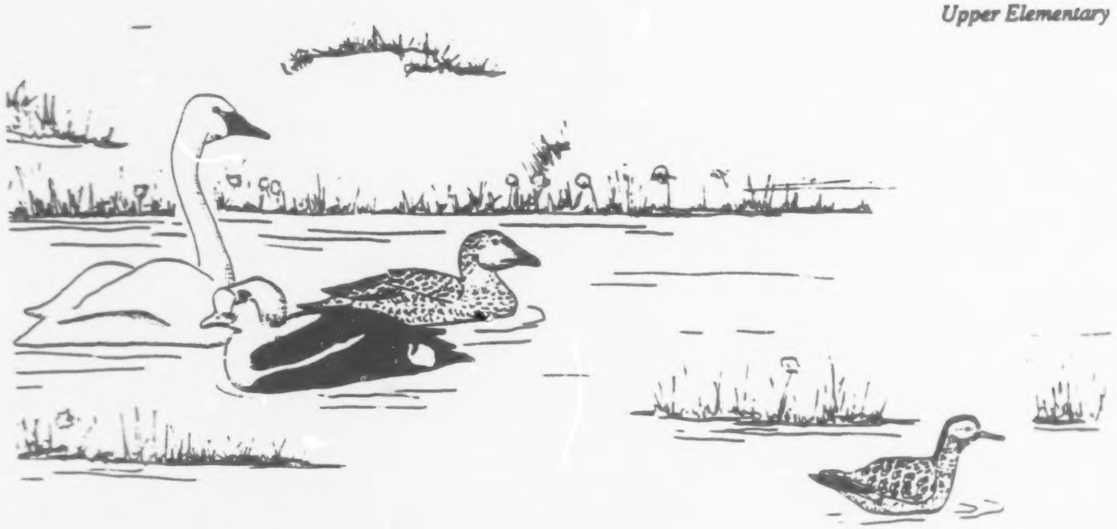
PERSISTENT WINDS: Persistent winds are a feature of some, but not all tundra environments. They occur in coastal polar regions and at high elevations for basically the same reasons. Winds are the movement of air masses from one one place to another. They are caused mainly by differences in air temperature from place to place, and by the rotation of the earth. Cold air tends to sink, while warm air rises. When an air mass moves, other air must flow in to replace it. The temperature of a given air mass is determined by many factors, including the intensity of solar radiation, the varying reflectivities and temperatures of the surface over which the air passes, and the watervapor content of the air. Winds at high elevations are caused in part by differences in the air temperatures on mountaintops and in valleys. Because air masses can pile up on one side of a mountain, and large differences in air temperature can occur between high and low elevations, winds in mountainous areas are more severe and persistent than anywhere else. As an example, winds of 45-65 mi per hr (74-105 km / hr) with gusts of up to 100 mi per hr (161 km/hr) are common on Mt. McKinley, even in summer. Winds in coastal polar regions are caused in part by variations in the temperature of air masses over ice, water, and land, along with the rotation of the earth.

Even in tundra areas where the occurrence and strength of winds are similar to those of mild environments, the cooling and drying effects of wind are intensified because of the absence of trees to block it.

LOW PRECIPITATION: Tundra regions have been called "cold deserts." However, the amount of precipitation that occurs in tundra areas varies greatly. Tundra in the far north receives less precipitation than some deserts [less than 2 in (5 cm)] and thus deserves the name. But some tundra regions of southwestern Alaska receive over 40 in (102 cm) per year, and some alpine tundra areas of Alaska receive 80 in (2 m) of precipitation each year!

PERMAFROST: Permafrost, or perennially frozen ground, underlies all tundra areas (except large lakes and rivers) in the far north. In western and southwestern Alaska, and in Alaskan mountains, it is discontinuous (patchy). In the Aleutian Islands, and on mountaintops at more southern latitudes, permafrost is absent, or rare. However, seasonal and/or nocturnal frost occur in all tundra soils.

Permafrost, when present, and seasonal frost both play an important part in shaping tundra lands and ecosystems. Some surprising topographic features of tundra are created by permafrost and frost action. See the Tundra Wildlife Cards section of this packet for photos and descriptions of these features.



WHY DON'T TREES GROW IN TUNDRA?

Cold temperatures, short growing seasons, low sunlight intensity, high winds, abrasion, permafrost, cold soil, and lack of moisture combine to prevent tree growth in tundra.

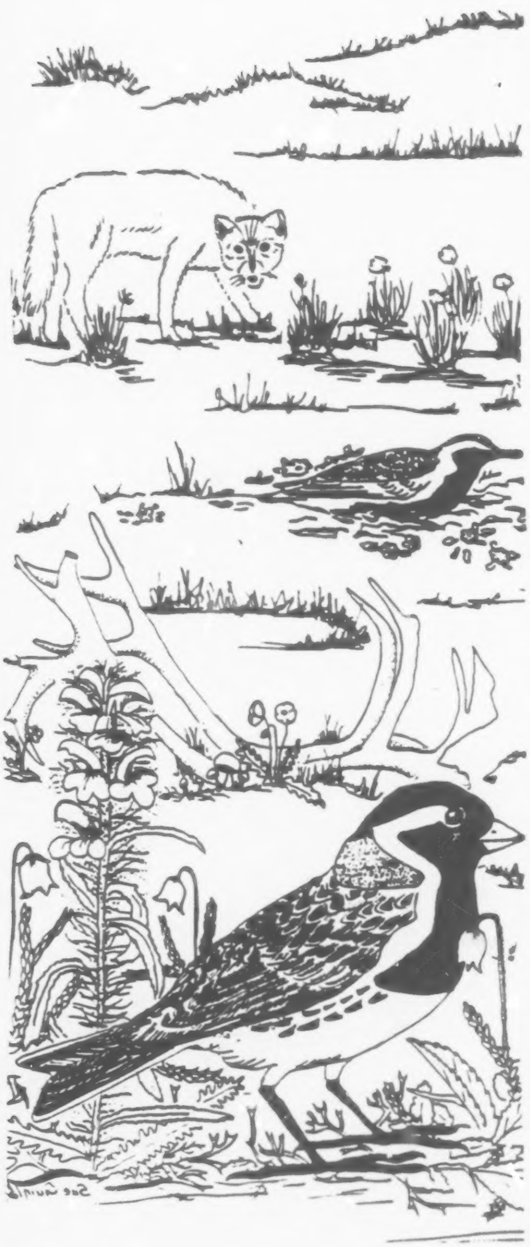
COLD TEMPERATURES: Cold temperatures present a problem because energy, usually in the form of heat, is necessary for the chemical reactions of life to occur. Anyone who has ever been cold knows intuitively that warm-blooded animals (birds and mammals) must stay warm in order to survive. Plants, fungi, and even microscopic living things also have minimum temperatures below which they cannot function. All metabolic processes occur in water solutions, so many living things have difficulty functioning at temperatures below the freezing point of water. Many important chemical reactions occur more quickly at warm temperatures than at cold temperatures. Plants cannot photosynthesize (make sugar from light energy, water, and carbon dioxide) at temperatures below 19.4° F (-7° C) and other metabolic processes (such as respiration) do not occur at temperatures much below this. But air temperatures in some tundra environments average less than this for most of the year. At Barrow, for example, the average temperature is less than 0° F (18° C) from October through May. In alpine tundra environments, air temperatures can drop below freezing every night of summer as well. Thus, living things that generate little heat themselves–plants, fungi, insects, other invertebrates, and microscopic organisms, simply cannot function most of the time in tundra environments. In general, trees do not occur where July temperatures average below 50° F (10° C).

SHORT GROWING SEASON AND LOW LIGHT INTENSITY: The length of time (summer) when activity and growth of plants and many other living things is possible is very short in tundra environments. Thus, tundra organisms must gather enough energy and minerals to meet their needs for an entire year during just a few months. (At high latitudes, low light intensity further reduces the amount of energy that plants can collect during the growing season.) Large plants, such as trees, may be unable to survive in tundra environments in part because they are unable to store enough energy and minerals during the short summer, to meet their needs in spring and fall.

WIND: Persistent winds make life in tundra even more difficult. Living things must generate more heat or have better insulation to stay warm in a cold, windy environment than in an environment with cold, still air. This is because moving air carries heat away from the surfaces over which it passes. The faster the movement of air (the stronger the wind), the faster it carries heat away. The cooling power of air at 10° F (-12.2° C) with a 30 mph wind is the same as still air at a temperature of -33° F (-36.1° C). Persistent winds thus severely reduce the length of time that tundra environments are effectively warm enough for living things to function.

Wind also speeds the evaporation of water and can dry, or dessicate, leaves, and other living tissues. In dry environments, (such as some tundra) the drying effect of wind can be more harmful than its cooling effect. The living cells and tissues of most plants and animals will die if dried.

Wind also carries particles of dust, ice, and snow which cut and wear down any objects over which they pass. The living tissues of most plants, fungi, and other living things are easily damaged by constant scouring by these wind-blown materials. Every winter, anything that sticks up above the snow is soon cut, worn, and killed by the abrasion of ice crystals on the windward side. The abrasive power of wind borne ice crystals is another reason that trees do not survive in tundra environments.



PERMAFROST: Permafrost also contributes to the unsuitability of tundra for trees. Permafrost prevents tree roots from penetrating deep into the soil. Without a strong anchorage, any that grow up into the wind will be ripped out of the ground. Additionally, tundra soils are very cold, particularly in areas underlain by permafrost. This slows root growth, and reduces the ability of roots to take up water and minerals from the soil.

Since water can not penetrate it, permafrost also traps moisture in surface soils. Poorly drained permafrost ground soon becomes saturated with water, even in areas with desert-like precipitation levels. Most trees can not grow in water-saturated soils.

TREELESS TUNDRA IN A MILD CLIMATE:

The climates found at low elevations in coastal southwestern Alaska, the Aleutian Islands, and on Kodiak Island are not nearly as severe as those found on top of mountains and in arctic Alaska. In these regions, winter temperatures seldom drop below 10° F (-12° C), and the summer growing season is 1-2 months longer. While the wind seems persistant without trees to block it, it actually does not blow anymore in these areas than in other parts of coastal Alaska where trees do grow. So why are there no trees in the aforementioned areas? Scientists are still debating about the reasons. One popular idea is that trees have just not reached these areas. Most of these areas were covered by ice, separated from other land by ice or water, or had much colder climates up until about 10,000 years ago. When the glaciers retreated, trees returned to the newly exposed land slowly--encroaching from areas where some had survived the last Ice Age, (such as interior Alaska and parts of the Pacific coast). According to this hypothesis, trees have just not yet reached the expanses of suitable land in southwestern Alaska, or in the Aleutians, but could become established there in the future. The westward spread of tree seeds into coastal areas may be hampered by the strong winds that blow from the coast toward the inland forests. Some scientists argue that the treeless ecosystems on the Aleutian Islands do not fit the criteria for tundra, and instead should be called grasslands, or meadows.

Introductory Activity 1.

Objective:

Students will be able to picture a tundra environment and will associate long, cold winters, wind, and the absence of trees with the tundra environment.

Skills:

LANGUAGE ARTS: Listening, memory, visualization; ART: drawing, illustration

Materials:

One to several copies of The Story of Dicrostonyx torquatus (this packet), pictures of tundra animals (from this packet or other resources); pencils or pens, drawing paper, yarn, hole punch, or staples for binding student books, photocopy machine to make copies of the class book.

Procedure:

SUMMARY: After reading or listening to a story about lowland tundra animals, students will draw pictures to illustrate the story and make a coloring book.

1. INTRODUCE THE STORY TO STUDENTS: Explain to students that you have found a story about some Alaskan animals, but that the story does not have any illustrations, or pictures. Since it doesn't have any pictures they will need to use their imaginations to picture the places and animals in the story. Later, they will help to illustrate the story. The story is about an animal that scientists have named Dicrostonyx torquatus. You may want to write this out on the board and explain that scientists have given all animals long names such as this. These scientific names are derived from Latin and Greek and are used so that scientists all over the world, no matter what language they speak, will know what animal other scientists have written about.

2. READ THE STORY. You may choose to have students read the story individually, or divide the class into groups and have each group read the story aloud. (The story could also be read aloud to the class by the instructor, or a student who is a good reader.)

3. DISCUSS THE STORY. Ask students to name and describe the place where the animals in the story live. Is it flat or mountainous? Do trees grow there? Is it hot or cold? Does the wind blow a little or a lot? Is the winter long or short? Is it light or dark in the winter? Is the summer warm or cool? Short or long? Do any animals besides the lemming live there? What ones? Are different animals present in summer than in winter?

4. STUDENTS ILLUSTRATE THE PLACES, EVENTS, AND ANIMALS IN THE STORY. Have each student draw 1 coloring-book type picture (using a black pen or pencil) to illustrate the place, animals, or an event described in the story. (You may let individuals choose a favorite part, or assign specific parts to various students.) Encourage students to use reference materials, such as the Alaska Wildlife Week Tundra cards and poster, and books about Alaskan animals and environments as references to make their illustrations of the animals and the environment more realistic, if desired.

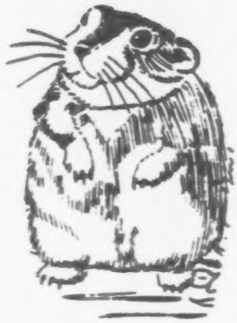
5. REPEAT THE ABOVE STEPS UNTIL YOU HAVE COMPLETED THE STORY.

6. PUT TOGETHER A BOOK CONTAINING THE STORY AND STUDENT ILLUSTRATIONS. Combine all the pictures with the text to make a class book. This could be photocopied so each student has their own copy, or shared with other classes in the school. Individual owners could then color in all the pictures.

[Alternatively, have students make a mural showing the four seasons described in the story.]

Evaluation:

Have students complete Worksheet 1a.



The Story of *Dicrostonyx torquatus* The Collared Lemming

by Susan E. Quinlan

CHAPTER 1. WINTER–A WORLD TO DISCOVER

Dicrostonyx torquatus, or Di for short, was a collared lemming. She lived on the tundra in northwestern Alaska. On the day she was born, the temperature was 30 degrees below zero and the tundra was frozen under a blanket of snow. Icy winds howled through the dark winter air. Tiny Di and her litter mates (brothers and sisters) were born with their eyes still closed and with no hair. They would have frozen in the cold air. Instead, they were warm inside a nest of grasses that their parents had built beneath the snow. The tiny lemmings slept and drank milk from their mother. Slowly they grew soft fur and opened their eyes.

One day Dicrostonyx was suddenly wakened by a pinch on the back of her neck. She squirmed and twisted only to find that she was hanging from her mother's mouth. A terrible smell filled the air of the nest. That horrible smell and her mother's strange actions made Di feel very afraid. She hung limp as her mother carried her out of the warm nest. Her mother then ran down a long, dark tunnel. Di's back end and feet felt icy cold when they brushed against the sides of the tunnel. Di sensed that her mother was scared too. Her mother hurried through one tunnel, then another. Finally she dropped Di inside a new grassy nest and then left. Di fluffed her fur out and curled into a ball to keep warm.

Di's mother returned in a few minutes. She dropped the littermate that she carried, then stopped. She listened carefully and sniffed the air. Di did the same. She heard the wind overhead. Wssshhhhhh, Wshhhhhhhhh, it whistled. She smelled the grasses of the new nest, her parents, and her littermates. And, very faintly, she smelled that terrible odor that she had noticed in the old nest. Di now knew that the awful smell meant danger. For now though, she was safe in the new nest with her parents.

Di and her littermates grew larger over the next few days. Soon there was not enough milk to feed all the growing young. Di soon felt hungry and the nest felt too crowded. So she left the nest. It was colder outside, but Di stayed warm because by now she had grown long fur. She slowly walked down the snow tunnel away from the nest. She looked, listened, and smelled all the new things she found. Soon she smelled something that made her remember she was hungry. She dug through the snow without thinking. Two shovel-like claws on her front paws helped Di scrape and dig through the hard snow. She found a small willow plant. Di filled her stomach with the twigs and buds of this plant. Then she began exploring again.

Di scurried from one tunnel to another for the next several weeks. She slept in nests that she found along the way. She ate whatever smelled good. Di could not find very much to eat. So she had to move further and further away from the place where she was born.

One day she found a tunnel that ended above the snow. Di cautiously peeked out into the open air. Ice crystals blown by a strong wind blasted into her face. The wind bit the tip of her nose and her breath turned to white fog. Di was still curious. She poked her head out further and saw a small hill. The hill was only 2 feet tall but to Di it looked very large. She scampered up it to find out what was on top. She found a patch of ground without any snow. The frozen soil was bare and brown. Di saw only a few small plants. The dead leaves and stems of these 2 inch tall plants spread over the ground like mats. Di ate a few buds that she found hidden under these dead leaves. Then she looked around. Flat, snow-covered ground stretched out as far as she could see. There were no trees or mountains to block the view. The sun was just above the southern horizon. It lit the sky with a reddish light.

Just then Di heard a noise. Crunch, crunch! Di dove back into her snow tunnel. Then she turned around and looked out carefully. She saw six giant beasts moving towards her. The crusty snow squeaked and snapped beneath their feet as they walked. Their short legs were almost hidden by long, wooly fur. Each one had horns that looped down either side of their shaggy faces. They stopped to paw the ground as they moved nearer to Di. They nibbled at some plants, then stopped to chew. The muskoxen did not seem to notice the bitter cold and wind. But Di suddenly felt cold. She turned and ran back down her tunnel to a warmer spot beneath a large drift of snow.

Di dug her own tunnels to find food during the next few months. She learned that it was warm beneath soft, deep snow and cold under the crusty snow. She also found many new things. One day she found a beetle that was frozen. Another day she found frozen berries. She ate these. She also nibbled on the frozen buds of willow and gnawed on the stems of grasses.

Di soon learned to recognize the sounds of other animals. She knew the sounds that other lemmings made as they gnawed on twigs. She knew the sound of muskoxen crunching through the snow. And she also learned to recognize the sniffing and pat, pit, pat of a hunting arctic fox. Di knew she must fear this sound. So whenever she heard it, she sat very, very still.

Each day in the snow tunnels was just like the last. Di dug tunnels through the snow. She looked for food and found it. She listened to the sounds around her and always hid when she heard a fox. The arctic tundra provided Di with food, shelter, and places to hide from her predators. She could not have had a better home.

CHAPTER 2. SPRING--CHANGES IN THE AIR

Di often dug tunnels to the surface of the snow just to see the world above the snow. Once when she dug a tunnel to the surface she saw another tunnel in the snow just a few feet away. She saw nothing around except white snow, so Di decided to have a closer look at it. She noticed that the sky was brightly lit out in the open. The wind was still and the air seemed warmer than ever before. Di began to explore the white world around her. She looked, listened, and sat on her haunches to sniff the cold air. But she did not see the large white bird that sailed quietly over the snow toward her. Its large black claws stretched out toward her back. Suddenly, Di rushed into the nearest tunnel--she barely noticed the owl's shadow in time. This time the snowy owl would have to search for a some other lemming to eat for its dinner.

Di's tunnels through shallow snow were light almost all of the time now. They had been dark all the time when she had first begun living on her own. Now it was almost too bright to see outside as the snow glistened and flashed in the sunlight. Di, curious as ever, still regularly visited the snow surface. But after her encounter with the snowy owl, she was much more careful.

One day, as she contently gnawed on a willow branch, Dicrostonyx heard a new sound. It was a beautiful, melodic whistle. She hurried up to the surface to see what was making the pretty sound. The wind was howling outside the tunnel. It was hard to see through the blowing snow. When she heard the beautiful sound again, Di spotted the singer. It was a small bird with striking black and white feathers and a small cone-shaped bill. The snow bunting was perched on top of a small snowbank near the entrance to one of Di's tunnels.

After that day, Di noticed many changes in her world. The snow changed to ice in some places. Di could not dig through the ice. In other places, the ends of Di's tunnels simply disappeared. The tunnels in deep snow that were once warm, became wet and icy. Some filled up with water. Di got very cold when her fur got wet. So she began to avoid the tunnels in the deep snow and started spending more time on top of the snow. Her fur was brown, so she was camouflaged when she hid amongst the brown leaves of the tundra plants. None of the plants were more than a few inches tall. Di had to be very still when she wanted to hide.

This was a dangerous place and time for a lemming. Di saw, heard, or smelled an arctic fox almost once every week. Twice she smelled the horrid odor that she remembered from her days with her mother. Once she saw an owl carry off a lemming that had been too careless. These events made Di wary. She sniffed the air often. She always looked carefully before going above the snow. She moved slowly. And she listened, even for faint noises.

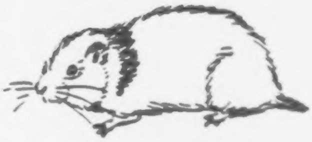
Cack, cack, cack, get-back, tobaggo, tobaggo! Di jumped nearly 3 inches off the ground when that loud cackling call exploded behind her. She raced under a tussock of grass and sat with her heart pounding. Tobaggo, tobaggo, tobaggo! Di carefully peeked out of her hiding place. She saw a ptarmigan eating willow buds. It had a brown head, a white body, and bright red combs over its eyes. Tobaggo, Tobaggo, Tobaggo! it called.

Di saw a new bird every day. Most were flying to other places. They came, and left, in great flocks. Often she heard large flocks of birds flying over. Their wings whistled in the wind. And most of them called out. Honk Honk! Honk! Quack...quaaack, quaack. Phsss, phss, phss. She heard the sounds during the sunlit day and in the short twilight of night. Perhaps Di did not know it, but spring arrived with the birds.

CHAPTER 3. SUMMER–A DIFFERENT WORLD

The weather often changed as spring turned into summer. One day was warm and the snow melted. Then snow fell and the winds howled the next day. Soon, however, Di could not find snow to tunnel through. She had to swim in places where she had once run through snow. She found flattened piles of wet grass in places where she once had built warm nests. Di, like all the lemmings, was forced to move to high spots on the tundra. Water covered everything else. Di could not find many places to hide, because few plants grew on the dry spots of tundra. Usually she hid under the dry leaves of a grass tussock.

Soon, the song of the snow bunting and outbursts of ptarmigan were hard to hear because the air was filled with the calls and songs of many kinds of birds. Lapland longspurs flew high into the air to sing songs that sounded like ice tinkling in a crystal glass. Boom, boom, boom, the drum-like calls of



into the air then dove toward the earth. "Psssssssssssssssh!" they whistled. "Ah ha leeek, ah ha leek" the calls of oldsquaw ducks rose from every lake and pond. But even these were drown out by the loud, haunting cries of loons: Hulawhoooo, Hulawhooooo.

The birds began nesting almost as soon as they arrived. Loons, geese, and eiders nested on the tiny islands in the midst of frozen tundra lakes. Sandpipers nested in the bare spots between patches of melting snow. The tundra was blanketed with snow when another snow storm passed through. The nests, eggs, and incubating birds were soon covered by wet snow. The birds could do nothing but wait for the snowstorm to stop. If they moved off of their nests, their eggs would get too cold.

Di waited for the snow storm to end too. The snow was too wet to tunnel through, so she hid under a grass tussock. When she felt the ground shaking, she poked her head out to look for muskoxen. But she saw something else. The long-legged animals trotting toward her were thinner than the muskoxen. They had short fur and thin antlers. They moved quickly, barely stopping to munch on the grasses and sedges. Di saw 20 caribou that came close to her. Nearby, tens of thousands wandered over the tundra.

Di had much on her mind during these days of early summer. She had to dodge the hooves of the caribou. Jaegers, a new kind of bird predator, had appeared with the great hordes of other birds. Di had to be very careful to keep hidden from them, and from owls. She listened for foxes and often sniffed the air for the smell of that unknown danger.

But Di found many new things to eat. She found green leaves and beautiful flowers on plants that had seemed dead during winter. The tundra was dotted with yellow, white, blue, and purple flowers. As Di feasted on this new variety of food, she grew large.

Many tundra animals, like the birds, were soon busy raising young. Within 2 weeks after the caribou arrived, almost every cow gave birth to a calf. The muskoxen had their calves in the willows down by the river. Every day arctic foxes trotted across the tundra to carry lemmings, birds, eggs, and other prey to the 4 young in their underground den.

Soon Di found a mate, and like the other tundra animals, began raising young. She and her mate dug a tunnel into the dry soil on the edge of a small rise in the tundra. Di discovered that just a few inches underground, the soil was still frozen solid. Di could not have found any warmer place to build her nest. The frozen earth she found, called permafrost, underlies nearly all of the lowland tundra in Alaska, so she could not have found a warmer place to nest. She built a warm nest of grasses, muskox fur, and ptarmigan feathers to help keep her young warm in the cold burrow.

As the days grew warmer, many kinds of insects began to appear. Bumblebees in yellow and black fur coats hatched from eggs that had been buried in the soil. They soon buzzed from one flower to the next. Yellow, blue, orange, white, and even black butterflies and moths came out of the chrysalis' and cocoons in which, as larvae, they had slept through winter. Flies and mosquitos hatched from the eggs that had survived winter. They soon filled the air with a constant hum: Bzzzzzzz Bzzzzzzzz Bzzzz. Every warm-blooded creature from caribou to lemming, goose to longspur, soon knew the annoying sounds and bites of the mosquito hordes. Caribou often ran wildly across the tundra to try to escape these and other insects.

The summer season passed quickly. One day, the caribou herd headed inland on another part of their endless migration. The eggs in hidden shorebird nests turned into long-legged, downy chicks. Soon after hatching, these chicks hurried after their parents in search of insects to eat. Broods of ducklings followed their mothers around the edges of the tundra ponds. Meanwhile flocks of male birds, and female birds whose nests had failed, headed back south. Long trains of eiders rushed past in a mirror image of their northward rush just 2 months earlier.

Areas that were flooded with water early in summer dried as the water slowly evaporated. Soon, white tufts of cotton topped the sedges, and blanketed the tundra like patches of snow. The tundra's other flowers turned to seed pods. One August day, the temperature stayed below freezing for several days. Ice formed on the small tundra ponds, and frost covered the plants. The never-ending hum of the insects stopped. Summer had come to its end.

CHAPTER 4. FALL–A MYSTERY SOLVED

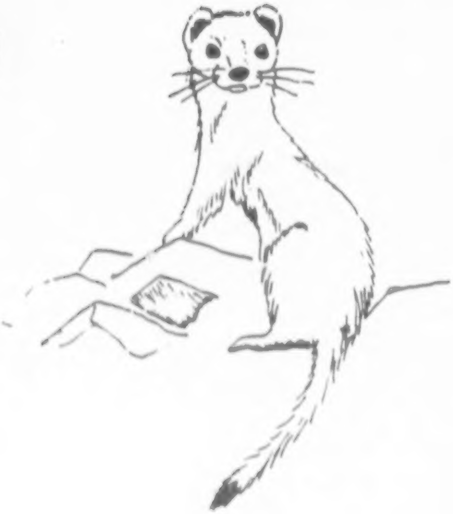
Di had to be very careful as summer turned to fall. More predators were looking for lemmings than ever before. Not only were the adult foxes hunting, but their pups were out of the den and had begun hunting on their own. The jaegers' chicks were now large and needed more food than before. Both adult jaegers were busy hunting almost 24 hours a day in search of enough food for their demanding young. The pair of snowy owls had raised 5 young, and all of them were out of the nest. Di often spotted their yellow eyes peering at her. Di was also careful because she sometime smelled the terrible scent which she knew meant danger.

Each day the temperatures grew colder. The wind stung as it lashed across the land. Frost covered the tundra plants each morning. Small flurries of white snow swirled across the tundra. Di spent most of her time hiding amidst the cotton grass and eating the sweet berries that the frosts had ripened. She also spent some time grooming her fur. Her short brown summer coat was falling out and a long white winter fur was growing in. Arctic foxes, tundra hares, and ptarmigan were also beginning to turn white.

Di noticed that a period of darkness began to occur each day and that it seemed to grow longer with each passing day. The tundra was quieter than it had been earlier. Not only were the insects silent, but the birds were too busy feeding to sing or call. Each bird needed to put on a layer of fat. The fat would give them the energy needed for the long long journey south. As each bird gained the needed weight, it lifted off and headed south. Di often heard the honking of a flock of geese as they saile overhead. Honk, honk, honk–they called as they left.

One day, Di awoke from a nap and felt that her world was somehow different. She ran to the entrance of her underground tunnel. It was covered by snow. Di pushed her nose through the soft powder to try to find the outside world. She noticed by the dim reddish light that the short, sunlit part of the day was almost over. All around her the tundra was white. Snow was everywhere. It covered the yellowed leaves of the willows, the brown leaves of the sedges, the red of the bearberry, and even the brown patches of earth. The wind was blowing again.

The wind grew colder. More snow fell. The tundra lakes froze over. And the sun shone for a shorter and shorter length of time each day. Dicrostonyx felt at home in this cold world. She tunneled one way and then the other through the snow. This was the world she had known as a young pup. She liked the warmth of the snow blanket and the darkness of her tunnels. Di started building a warm nest of grasses in a spot she recognized as one she had used last winter. She also dug a tunnel to the surface of the snow so that she could occasionally go and look out.



On one of her visits to the surface she saw a strange white animal that she had never seen before. Its long body, short legs, and long tail tipped in black gave it an odd look. It moved by bringing its hind legs up near its front ones, then moving its front legs out. It looked a little like a very large and very fast caterpillar. Always cautious, Di watched it carefully and sniffed the air. The animal was downwind of her so she could not smell it. But she noticed that it was also sniffing the air and it seemed to be moving right towards her. She backed further into her snow tunnel, but continued watching.

It was coming towards her even more quickly now. Something about its approach reminded Di of a hunting fox, so she decided to run away. She slipped down her snow tunnel away from the animal. Then she took a side tunnel that would lead to a spot downwind of the animal. Perhaps if she could sniff its scent, she would know what it was.

Di stopped and sniffed as she neared the end of the downwind tunnel. She nearly froze in terror when she smelled the strong odor of the danger she had known since her earliest days. She knew she must hide. But she had not had time to dig many tunnels in the snow. She peeked out the tunnel she was in and saw the tip of the weasel's tail disappearing down the entrance to the tunnel she had just been in. The animal's long narrow shape was just right for traveling in lemming tunnels. Di suddenly knew that the weasel was hunting her. If she ran back down her tunnel she would run right into it.

Di decided to run over the snow surface instead. Scampering across the snow, she ran one way, then the other. The wind had formed a crust on the snow so it was easy to run across it. Di did not look back to see if the weasel was following. She just kept running as fast as she could. The winds had blown the snow into drifts. Di had to run up and down, up and down over these. In her rush Di did not see the drop-off near the edge of a frozen lake. She tumbled head over heels down the drop-off. Down, down, down she went. When she finally landed in a snow bank. She lay stunned for an instant. Then she dove into the snowbank. She dug as fast as she could and kicked snow to fill the tunnel behind her. At last she was too tired to dig further, so she stopped. Her heart was racing so fast she could hardly hear. But she listened carefully and sniffed the air. She heard nothing and could not smell anything. Still she lay quietly. She did not want to make any noise that would help the weasel find her. She soon fell asleep.

Di started when she awoke. She calmed down only after sniffing the air. It smelled fresh and clean. Di had escaped the weasel. Now it was time to find food. Di dug tunnels through the snow of this new area. When she finally had time to peek above ground, she felt the icy blast of winter winds and the freezing chill of below zero temperatures. She could see only darkness. Winter was a silent season. The wind howled. The ice groaned. Sometimes the sound of Di's teeth gnawing on willow twigs echoed through her tunnels. Di lived in her snow tunnels during these months of wind, snow, and darkness. The northern lights lit the dark sky over the tundra in February. Di cared for another litter of young under the snow. They would begin their lives, as she had, in the darkness of a warm grass nest beneath a blanket of snow.

Permafrost Puzzles...............SCIENCE...........INDOORS/OUTDOORS

OBJECTIVES:Students will become aware of the effects of permafrost on the soil surface and landscape by simulating permafrost in a pan, acting out the formation of ice, and freezing water.
MATERIALS: 2 cake pans, a glass or plastic container with a tight lid, freezer, soil, water.
PROCEDURE:
1.PREPARATION: Fill 1 cake pan with at least 2 inches of moist soil, then freeze it. Fill another cake pan half full of moist soil, but do not freeze.
3. DISCUSS THE TERM PERMAFROST: Ask students what is meant by the term permafrost. If they do not know, explain that this is a term used to describe soil that is frozen year-round. Ask whether this occurs in the area of your school.

If students don't know the answer, this is a good opportunity to find out. In the fall, you can find out by driving a rod into the ground as far as possible, or digging a hole until you hit ice. If you are doing the lesson in late spring, the ground may still be frozen even in areas that do not have permafrost. Discuss with students when they think the ice in the ground melts. Check the depth of the ice weekly until school is out and encourage students to continue checking throughout the summer to find out whether or not permafrost occurs in your area. Alternatively, have students check a copy of the Environmental Atlas of Alaska (see the reference list) and find out if permafrost occurs in your area.

After students understand what permafrost is, ask them how they think permafrost soil might be different from unfrozen soil. Encourage them to make some predictions, or hypotheses, by asking questions–would it be warmer or colder? harder or softer? Would it soak up more or less water? Would it take up more or less room?
4. TEST STUDENT PREDICTIONS: Retrieve the pan of soil from the freezer and have students test their predictions. Have a student try to stick a fork in the soil to find out if it is harder or softer. Ask students how the hardness and temperature might affect plant growth. Have students pour a tablespoon of water on the two pans of soil. What happens? Which one soaks up the water?
5. DEMONSTRATE THE EFFECTS OF FREEZING WATER: Completely fill a glass or plastic container (with a lid) with water. Ask students what they think will happen when you place it in the freezer. Conduct an experiment to find out. Can students explain why the container broke? Help them recognize that water expands (gets larger) when it freezes. So there was not enough room in the closed container to hold the frozen water and it pushed out. Have students pretend they are water and act out the process of freezing. Have all the students stand in a circle. Draw a circle around them, so that all students are inside it. Explain that they each represent a water molecule. While liquid, the water molecules can "stand" side by side, but when water freezes, it forms ice crystals. Ask students to form ice crystals–each "molecule" must spread their arms straight out to the sides. They must touch the fingertips of another "molecule," but no other part. What happens? (They have to spread out and they don't fit in the circle.)
6. USE THE PERMAFROST INFORMATION PROVIDED IN THE TUNDRA WILDLIFE CARD SUPPLEMENT TO SHOW THE TOPOGRAPHIC FEATURES OF PERMAFROST SOILS. Have students make clay or play dough replicas of each of the features.

A walk across the tundra........... Language Arts....Indoors/Outdoors

OBJECTIVES: Students will demonstrate their awareness of the tundra environment by making up and acting out a play about the tundra.
MATERIALS: none.
PROCEDURE:
1. Divide the class into small groups. Assign each group one of the seasons and ask them to make up a short play about walking across the tundra in that season. Encourage them to think about the wind, the cold, what the ground would be like, and what animals and plants they might encounter. One student can act the person in the play, while the other students might act out various animals or plants. Students may make any kinds of sound effects they want to, but are not allowed to use words. Allow about 15 minutes for them to figure out their play.
2. STUDENTS PRESENT THEIR PLAYS. Have students present their play to the rest of the class or other classes. Ask the other students to guess what season the players are acting out.

Alaska Wildlife Week Unit 3. © 1988 Alaska Dept. Fish and Game

TUNDRA AROUND THE WORLD ...SOCIAL STUDIES, SCIENCE

OBJECTIVES: Students will become familiar with the distribution of tundra environments around the world.
SKILLS- geography, use of an atlas, maps, and encyclopedias
MATERIALS: Copies of a blank map of the earth's continents or an enlargement of one on to butcher paper, an atlas, encyclopedias
PROCEDURE:
1. STUDENTS IDENTIFY THE MAJOR GEOGRAPHIC FEATURES OF THE EARTH. Ask students to draw in and label the following on their map: the equator, latitudes in 10 degree intervals, names of all continents, the 3 largest rivers on each continent, and the mountain ranges on each continent.
2. STUDENTS MAP THE BIOMES OF EARTH: Have students look at vegetation maps for each continent or country, and color in the kinds of environments on each continent, using different colors to show tundra, forest, desert, and prairie.
3. DISCUSS THE DISTRIBUTION OF TUNDRA ON EARTH. Have students use their maps along with a map showing political boundries to make a list of countries in the world that contain tundra, and determine which countries and places have the most. Ask students to figure out why there is more tundra in the northern hemisphere than in the southern. Can they figure out that there is little land at high southern latitudes where the environment is cold enough to cause tundra?

TUNDRA PICTIONARY....... ......LANGUAGE ARTS / ART

OBJECTIVES: Students will recognize the topographic features of permafrost soils and become familiar with the terms used to describe them, along with other vocabulary words.
SKILLS: vocabulary building, teamwork
MATERIALS: copies of the pages describing the topographic features of tundra and tundra glossary, vocabulary words and names of topographic features written on index cards, pencil and paper
PRODEDURE:
1. STUDENTS REVIEW THE TUNDRA FEATURES: Allow students 15 -20 minutes to study the descriptions of tundra topography, and the glossary. (Or, assign these as reading homework.)
2. STUDENTS PLAY PICTIONARY: Divide the class into groups of 3-5 students. Each group should have an area of blackboard and chalk, or paper and pencils. Tell students that you will show one player on each team a "tundra word." That player will draw, while the remaining players try to figure out what word the drawer is attempting to communicate in their drawing. The person who draws may draw a picture of the object the word describes, or any pictures that might help their teamates guess the word. All teams will play at once with the same word (one player drawing and the others guessing). The first team to guess the word wins 1 point and the chance to give its definition. If they can define it they earn 2 more points. Once a word has been guessed correctly and defined, each team selects a new artist. Show the new artist of each team the next "tundra word" and play round 2. Continue as long as possible, or until all of the glossary words have been correctly defined.

A Tundra Field Guide..............................Science, Social Studies, Art

OBJECTIVES: Students will become more familiar with the wildlife of their local area.
SKILLS: reading, observation, art
MATERIALS: Tundra Wildlife Cards (this packet), references on Alaska wildlife.
PROCEDURE: 1. SORT THE WILDLIFE CARDS: Have students review all of the tundra wildlife cards and sort out those organisms which might occur in the local area. (Some species, like pika, have a limited distribution in Alaska, and might not be found near your school.) Then, have students look up additional information on the organisms on the remaining cards.
2. STUDENTS WRITE AND ILLUSTRATE THEIR OWN FIELD GUIDES TO LOCAL WILDLIFE: Have each student or group of students make up a field guide to local tundra wildlife. (The guide could be just on birds, or another group of animals, or it could include all living things in your area.) The field guide should contain information on how to identify the each organism (coloration, traits), where to look for it (its habitat), how large it is, and what seasons it is present in your area. Students can get this information from local experts (long time residents or biologists), reference books, and from observations. The field guide should also contain illustrations (either drawn by students or use the illustrations on the cards).
3. "FIELD TEST" THE GUIDES. Take a field trip to a tundra area and see how many living things shown in the field guide students can find. Are there any common living things that students did not show in their field guide? Encourage students to find out what unknown plants, insects, or other organisms are, and then add them to their field guides. If carefully done, these guides could be valuable for younger students or future classes.

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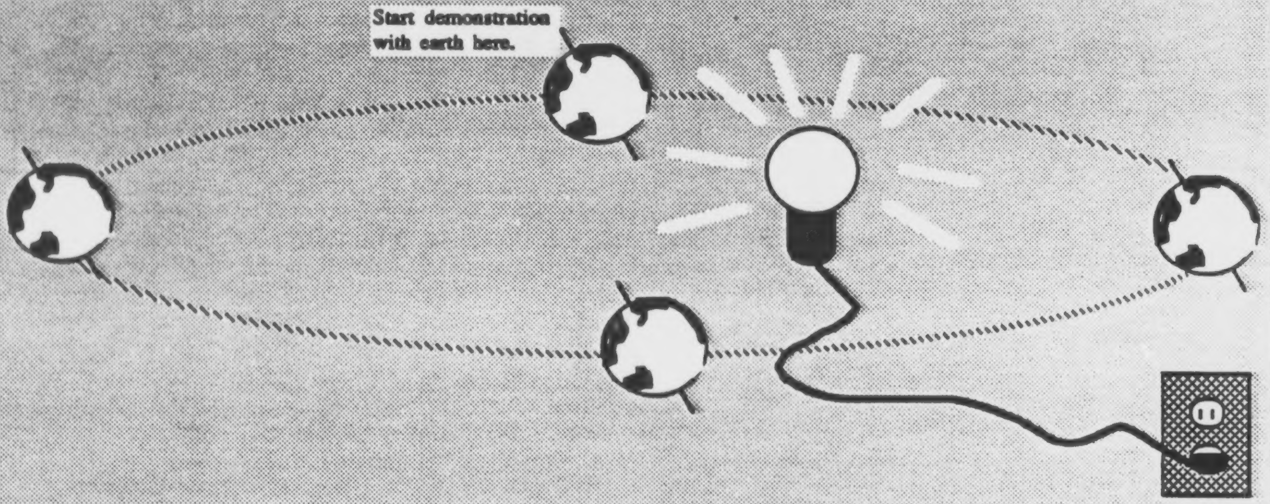
Understanding the North..Science
....Indoors



OBJECTIVES: Students will understand why the winters are cold and dark in the arctic.
MATERIALS: bright lamp, globe or styrofoam ball with pencil or wire.
PROCEDURE:
1. PREPARATION: Use a globe, or sketch the major continents on the styrofoam ball along with the equator and 66°33'N and S latitudes (the arctic and antarctic circles). Insert the pencil or wire through the center of the styrofoam ball. Set the light up on a small table so that you or a student can walk around it.
2. FAMILIARIZE STUDENTS WITH THE MODEL: Explain to students that the lamp represents the sun, and the globe or styrofoam ball represents earth. Show the the location of the north and south poles (the pencil in the styrofoam ball). Have students find Alaska on this model of earth. Next, show the tilt of the earth on its axis (23 1/2°) and demonstrate the earth's location relative to the sun. To begin with hold the earth in the equinox position--i.e. so that the axis of the earth is pointing along its revolution path rather than pointing into or away from it--see diagram. Ask students to examine the pattern of light and dark on the "earth". Demonstrate how the earth rotates, resulting in night and day.
3. DEMONSTRATE THE REVOLUTION OF THE EARTH AROUND THE SUN: Keep the axis of the earth pointed in the same direction and have students watch how the light and dark portions of the "earth" change as it moves around the "sun". Explain that the earth makes one revolution (circle) around the sun each year. Have students decide when it is summer in Alaska, and when it is winter. Can students figure out why it is cold and dark in the winter in Alaska? Ask them if it would be cold in the southern part of the globe when it is winter in Alaska. Is it ever winter at the equator? Use the model, along with questioning to help students see and understand why there are dark, cold seasons in the north and south, but not near the equator.
4. RELATE THE OCCURENCE OF COLD, DARK WINTERS TO THE OCCURENCE OF TUNDRA: If students have not previously learned where tundra occurs on earth, explain to them, that most of the tundra occurs in northern lands, above the arctic circle. See if they can figure out, by looking at a globe, why there isn't more tundra in the southern hemisphere. (Cold, dark winters occur in the north and south, but there is little land at high southern latitudes.)

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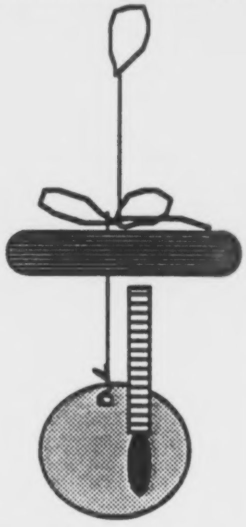
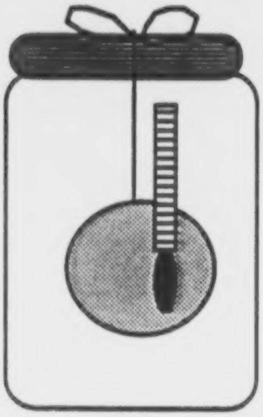
The Atmosphere Blanket..Science

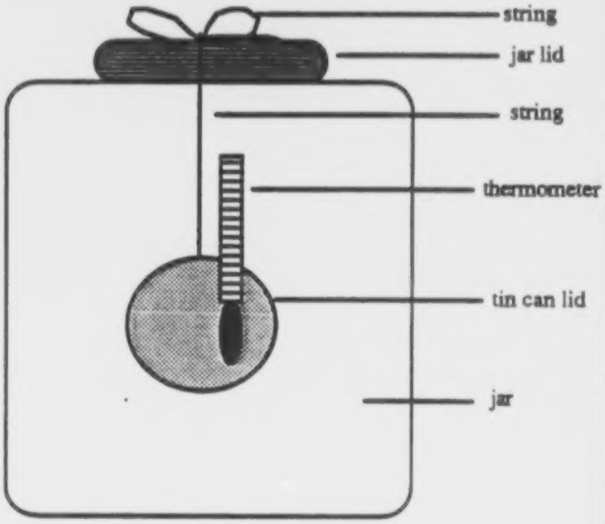
....Indoors/Outdoors



Prepare 3 of the above. Suspend a tin can lid from a jar lid with string. Tape a small thermometer to the metal.



Place one inside a small jar. Close the lid tightly.



Place one inside a large jar. Close the lid tightly.

OBJECTIVES: Students will understand that the atmosphere acts like a blanket around the earth and will understand that mountaintops are cold because the "atmosphere blanket" covering them is not as thick.

MATERIALS: Balloon, 1 large and 1 small glass jar with large mouths and lids, 1 extra jar lid, string, 3 small thermometers, tape, 3 tops from tin cans.

PROCEDURE:

1. DISCUSS THE CONCEPTS OF AIR AND ATMOSPHERE. Ask students to breathe in and out, then ask them what they were breathing. Ask them what "air" is. They are likely to say "it's nothing". Ask someone to blow up a balloon. Then ask students how nothing can take up space inside the balloon. They should begin to grasp that air is made up of something we can't see.

2. CAN AIR KEEP US WARM? Ask students to imagine having a coat made out of air. Could it keep them warm? Take a survey--how many think it would, how many think it wouldn't? Suggest that the class do an experiment to find out whether air can keep something warm. Set up the jars as shown in the diagram above. Have students record the temperatures of the metal inside each jar. Then, place all the jars outside. Have students check the thermometers every 5-10 minutes. Which items cooled the fastest? Why did those in the big jars stay warm longer? (Students should conclude that air can keep things warm.)

3. DISCUSS THE EARTH'S ATMOSPHERE: Explain to students that the earth is surrounded by a blanket of air called the atmosphere. Visually convey the atmosphere concept by wrapping a thin layer of cotton around a globe. Show how mountains stick up into the atmosphere, so that the blanket of air over them is not as thick. (Mountains stick up near the edge of the first layer of the atmosphere (the troposphere) into the stratosphere which has an air temperature of -50° C at its lower edge.) Have students think about their toes sticking out from under a blanket. Ask them why they think tundra occurs on mountaintops--even near the equator. (They may need to know that the outer atmosphere and space are very cold.)

EXTENSION: Investigate the value of air as an insulator further. Bunny boots, down coats, and air mattresses are ways that humans use air as insulation. Birds and mammals keep warm not because of the insulation provided by feathers and fur, but by the insulation provided by the air the feathers and fur trap.

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Worksheet 1a.
Tundra Words

Name________________________________

J O S E C J S A N D P I P E R F N D I O J I P O N D Q G N G G S
J I N J F R S D O I S L A B I N M N O C A B W E A S E L D S D R
M K O L M E N Q K B E Q M B H N B O P J C L F L M F L B K R J E
G A W F C G O C K M D D P G E C C R L J N J G B J N L K N E S M
H H B P A E I F G M U Q C F C Q E E H L P J A N I O H M Q T U M
B I U Q R A T D O M T O O J L T K J J H G S S A I R B Q I N N U
N K N J I J A D P G I D M B A O F Q C E S K O T A K D O L I L S
E Q T C B P V F F K T L O W P E W L H E K N I E N H A A Q W I T
X F I A O K E F N H A M S Y M Y I E L E A D C Q C A L E B G G R
O D N D U N L F B C L Q Q D O L O E R I Q P N H A G R H K N H O
K Q G L E O E I Q B N J U N G F E I G C O P S A N B H G G O T H
S Q I I N G O P O A D D I I H R C J Q C E O J E L I O I I L Q S
U I L P N Y M O B B A O T W T E L E O P I A O L A T A M B M F E
M O C L G L F Q J F K P O P R T I H P L B M P C M L E A M P N G
I I I L J O F B Q M D A J N O T M P F N F M N E A E B W I G N E
J B C I K P C P C I F C L F N U Q F J M E J E S A N F N P C G D
P E R M A F R O S T I N H I R B K F F S M J K D J C G O M O G J
P O I M E N X O F C I T C R A Q M F O M I A K J N O I K J D G K
H Y R D L G N I M M E L L E F K I O K F G N H A L P I N E C O A
J N R E H T R O N O C O L D D O G N H K G E D K G C N D E O Q M

Circle any words that accurately describe tundra, describe a place where tundra occurs, is a characteristic of a tundra environment, or is something you might find in a tundra environment. These 33 words are in the Tundra Word Search Puzzle--try to find them. You may use the Tundra Glossary, a dictionary, or other references to find out the meaning of any words you don't recognize.

barren
wetland
forested
soil
tropical
pingo
hot
muskoxen
lemming
high latitudes
flower

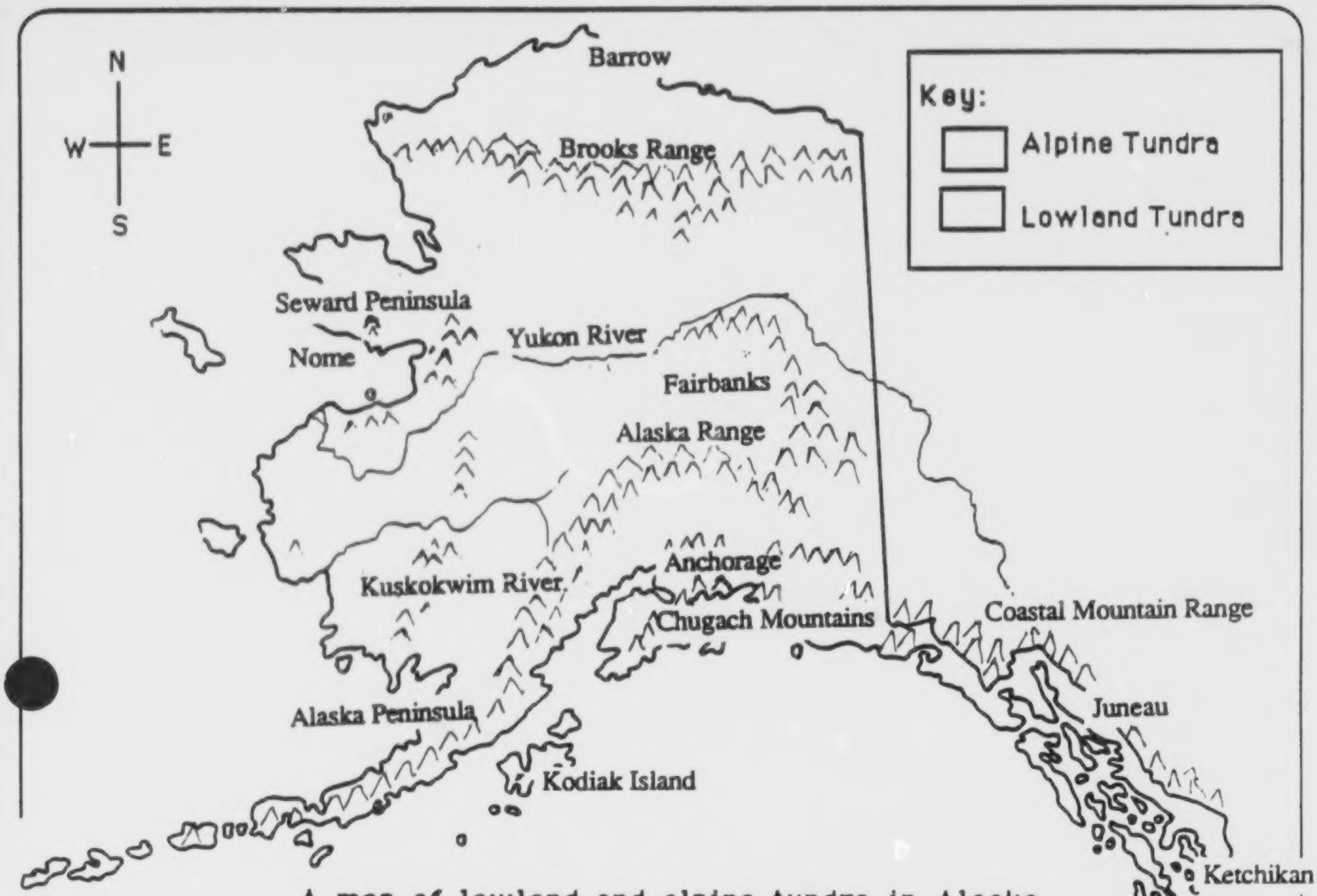
cold
sandpiper
jaguar
warm
sunlight
migrants
long winters
permafrost
high elevations
jaeger
flying squirrel

windy
air
dry
far north
low latitudes
short winters
sandpiper
treeless
arctic fox
mosquito
butterfly

weasel
water
short summers
Alaska
woodpecker
goose
polygon
caribou
chickadee
snow bunting
alpine

Worksheet 1b.
Alaska's Tundra

Name________________________


N
W
E
S
Barrow
Brooks Range
Seward Peninsula
Nome
Yukon River
Fairbanks
Alaska Range
Kuskokwim River
Anchorage
Chugach Mountains
Coastal Mountain Range
Alaska Peninsula
Juneau
Kodiak Island
Ketchikan
Key:
Alpine Tundra
Lowland Tundra

A map of lowland and alpine tundra in Alaska.

This map is not complete. It shows our state, Alaska. It shows some of the larger towns in the state. It also shows the mountain ranges in Alaska. But it does not show where lowland and alpine tundra occur in Alaska. You can finish the map by coloring in the places where tundra occurs.

Use yellow to color in the places where alpine tundra is found. It is found on the tops of all the mountain ranges.

Use red to to color in the places where lowland tundra is found. It covers the plains north of the Brooks Range. It also is found on the coast of western Alaska. Most of the western Seward Peninsula and most of the Yukon and Kuskokwim River Deltas are lowland tundra. Lowland tundra also occurs on the southern Alaska Peninsula and on southern Kodiak Island.

If your home town is not on the map, add it to the map. Circle the kind of tundra that occurs in or near your town.   alpine   lowland   both kinds

Be sure to color in the key to the map, so others will be able to understand what the yellow and red colors on the map mean.

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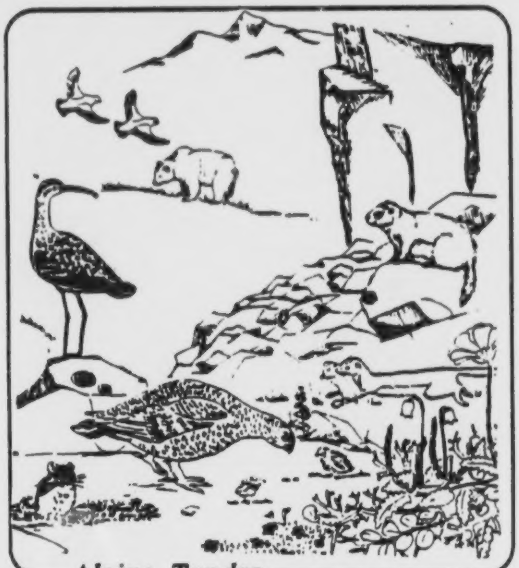
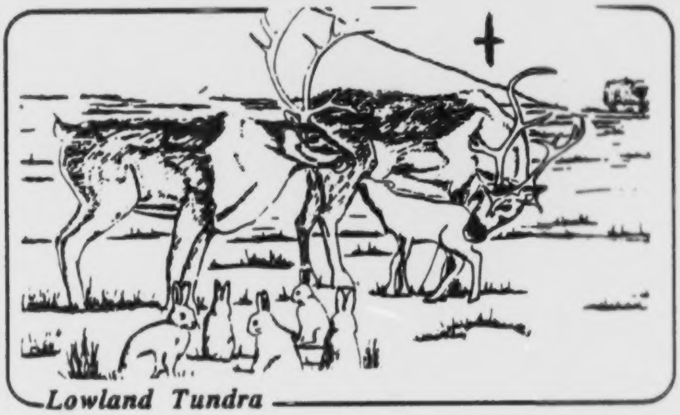
Lesson 2.

Vocabulary

alpine tundra, animals, fungi, lowland tundra, monerans, permafrost, plants, protists, solifluction, wetland



Alpine Tundra



Lowland Tundra

Objectives:

Students will be able to differentiate alpine and lowland tundra ecosystems, describe the characteristics and distribution of each in Alaska, and become aware of the variety and abundance of living things that occur in each tundra type.

Teacher Background

IS ALL TUNDRA THE SAME?

Nearly half of the land in Alaska is tundra, but not all tundra is alike. The term "tundra" is used to describe all ecosystems that share the characteristics of periodic severe cold, short growing seasons, persistent winds, and the absence of trees. These characteristics make all tundra ecosystems look superficially similar, but the non-living environments and the species of living things present vary between regions and specific areas. The two main types of tundra ecosystems that occur in Alaska are alpine and lowland tundra, but even within these categories tundra ecosystems vary from one region to another.

HOW DO ALPINE AND LOWLAND TUNDRA ENVIRONMENTS DIFFER?

- Alpine tundra occurs at high elevations (mainly on mountains) throughout the world, while lowland tundra occurs at low elevations in polar regions, coastal subarctic areas, and on subantarctic islands. In Alaska, lowland tundra occurs north of the Brooks Range, in northwestern and western Alaska. (The treeless environment in parts of coastal southwestern Alaska and the Aleutian Islands is also sometimes classified as lowland tundra, but it is warmer and moister than typical lowland tundra, and is sometimes classified as grassland.) Alpine tundra occurs on mountains throughout the state; it grades into lowland tundra in northern and western Alaska.
- Alpine tundra is a discontinuous habitat. It occurs in patches separated by the forests and wetlands of lower elevations, and the ice and snow of high elevations. Many alpine sites are like islands of tundra. In contrast, lowland tundra covers vast, continuous expanses of land, such as the North Slope and the Yukon Kuskokwim River Delta.
- The topography of alpine and lowland tundra differs greatly. Alpine tundra sites are characterized by abrupt changes in slope and aspect; flat and gently sloping areas are intermixed with steep slopes and cliffs. The underlying terrain of lowland tundra, in contrast, is generally flat, or gently sloping. However, wind, water, and permafrost continually shape and carve the surface of lowland tundra. In lowland tundra areas underlain by permafrost, topographical relief occurs, including thermokarst ponds, ice wedge troughs, thaw lakes, high and low-center polygons, and pingos,

ice-filled hills that can rise 164 feet (50m) above their surroundings, . (See the illustrations and descriptions of these features in the Tundra Wildlife Cards Supplement to this packet.)

- Daily temperature fluctuations are more extreme in alpine than in lowland tundra. The air at high elevations is less dense than the air at lower elevations. As a result, alpine tundra receives more intense solar radiation (less is filtered by the atmosphere) during the day, and cools more quickly at night. Freezing temperatures may occur at night year-round in alpine tundra. Long cold winters occur in both alpine and lowland tundra, but a 2-month period of darkness with little or no sunlight occurs only in tundra at high latitudes (mainly lowland).
- Most alpine areas receive more snowfall, and thus more precipitation, than lowland tundra. Alpine areas in northern Alaska receive about 20 inches (51 cm) of precipitation per year, but alpine tundra regions in southcoastal Alaska receive 100-200 inches (250-500 cm) or more. (In some southcoastal Alaska mountains, scientists have recorded as much as 18.75 feet (5.7 m) of snow in a single month!) In contrast, most lowland tundra receives only 4-20 inches (10-51 cm) of precipitation per year. This level of precipitation is comparable to that of deserts and arid grasslands.
- Contrarily, most alpine tundra is dry, while most lowland tundra is wet or moist. High winds, dry air, intense solar radiation, shallow soils, and good drainage due to the mountainous topography result in dry condtions in most alpine tundra, despite heavy snowfalls. However, some alpine sites have adequate or abundant water; snowbanks that melt slowly provide a continuous supply of water to sites below them, and water collects in depressions and flat areas of alpine tundra.

In striking contrast to the dry, rocky land of alpine tundra, most of Alaska's lowland tundra is wet or soggy during summer. This occurs because nearly all lowland tundra is flat or gently sloping, and is underlain by permafrost (perennially frozen soil). Water cannot seep through permafrost, and flows slowly over flat ground, so all of the water from rain and snowmelt remains on the surface in lowland tundra. Evaporation and transpiration (the release of water vapor into the air by plants) occur slowly due to the cool temperatures. Thus, many lowland tundra areas remain wet during the entire summer.

- Shallow soil, rock piles, rock outcroppings, and cliffs are important features of alpine tundra, though deep soil occurs in gently sloping areas. In contrast, most lowland tundra sites have deep soil and rock outcroppings are uncommon except in the high arctic.

The exposure of bare rocks in alpine areas results from soil erosion caused by landslides, avalanches, high winds, fast-running meltwater, solifluction (sliding of the active layer of soil atop the permafrost layer on sloping land), and frost-heaving.

Little erosion occurs on the relatively flat terrain of lowland tundra; most dead organic matter remains in place or is washed into lakes and ponds. Centuries of accumulation have resulted in deep layers of partially decayed material, or peat. Many lowland tundra areas are also periodically flooded by slow-moving rivers that deposit silt and organic material from upriver.

- Environmental conditions in alpine and lowland tundra vary considerably depending on latitude, elevation, aspect, and slope. Both types of tundra gradually change from very dry, cold environments with lots of bare soil and rocks, to zones where most of the ground is covered by lichens and mosses, and finally to a warmer, moister zone dominated by low shrubs. In alpine tundra, this variation occurs mainly over an altitudinal gradient, from high to lower elevations. Variation in lowland tundra occurs mainly along a latitudinal gradient from northern, arctic regions to more southern, coastal subarctic regions.

WHAT LIVING THINGS OCCUR IN ALASKA'S TUNDRA ENVIRONMENTS?

Considering the severe conditions of tundra environments, it seems surprising that any living things can survive in the tundra regions of the earth. In fact, some people mistakenly assume that tundra is barren and desolate wasteland. However, representatives of all five kingdoms of living things occur in tundra environments. Though generally fewer species occur than in milder environments, many of the species present occur in astonishing abundance. Many of the species of plants, animals, and other living things found in tundra do not live in other environments.

The numbers and variety of living things present decreases as the severity of the climate increases; thus fewer species of living things are found on the tundra in the far north than in the subarctic maritime tundra, and, in alpine tundra, more species are found near treeline than at higher elevations. Some kinds of living things occur in both alpine and lowland tundra. But, many alpine tundra wildlife require well-drained, dry, rocky, or precipitous sites that are not available in lowland tundra, while many wildlife of lowland tundra are aquatic or semi-aquatic and could not live in dry alpine tundra.

General information about the living things found in Alaska's tundra ecosystems is provided in the introduction to the Tundra Wildlife Cards that go with this packet. Also, see the three posters that accompany this packet for illustrations and photographs of many tundra wildlife.

Introductory Activity 2.

Objective:

Students will become familiar with the variety of living and non-living things found in alpine and lowland tundra environments and will be able to desscribe differences in these two environments.

Skills:

SCIENCE: observing, comparing, classifying.
LANGUAGE ARTS: oral communication skills.

Materials:

Posters of alpine and lowland tundra and tundra wildlife cards, both in this packet

Procedure:

SUMMARY: Students will compare the drawings and photos of alpine and lowland tundra and try to identify similarities and differences in the environments and living things present.

1. INTRODUCE THE POSTERS: Show the illustration of lowland tundra and ask students to name the environment it shows. Explain that there are two kinds of tundra found in Alaska and in the rest of the world. These are lowland tundra, the kind described in the story, and alpine tundra, shown in the other illustration. Bring out the poster of alpine tundra. Show the color photo poster with photos of the two types of tundra.

2. STUDENTS COMPARE THE TWO POSTERS: Divide the class into groups (or they may do this step individually). Explain that they have 5 minutes to list all the ways in which the two tundra environments are alike (similar). If necessary, use questions to help students notice some of the similarities. Do both environments have sunlight? air? water? dirt and rocks? Do they both include animals? plants? Are any plants and animals the same? Do the places look similar to each other? How? Are any kinds of plants missing from both environments? (trees) Have the group that develops the longest list read it off. Ask if other students can add anything to that list. List all the similarities on the board.

Praise students for finding these similarities and ask them why they think the two environments have some similar animals and plants. Can students predict that the two environments have similar climates–i.e. long, cold winters and short summers. Explain that the similar climates cause some of the similarities in the two environments such as the absence of trees.

3. STUDENTS LOOK FOR DIFFERENCES IN THE TWO ENVIRONMENTS: Next, explain that although alpine and lowland tundra are similar, there are also some differences between them. Ask the groups to find and list as many differences as they can find. Again, encourage students by asking questions, if necessary. Is the ground the same in both environments? How does it differ? (More rocks, slopes, and cliffs are present in alpine tundra.) Is there more water in one environment than in the other? Are the animals and plants the same? (Some are, some are not.) Again, have the team who found the most differences read their list. Ask others to identify any differences this group overlooked. List the differences on the board.

4. STUDENTS IDENTIFY THE LIVING THINGS IN THE TWO TUNDRA TYPES: Students may recognize some of the living things pictured in the two environments, but they are likely not to recognize some. Ask all the groups to identify (find out the names of) as many living things as possible (in each drawing) by comparing the pictures to those on the Tundra Wildlife Cards, or to pictures in other books about tundra and/or Alaskan wildlife. (Or assign each group to work on one poster only.) Ask each group to be prepared to point out each of the living things they list and to tell something about each creature.

5. STUDENTS COMPARE LISTS: Review the lists developed for each poster. Ask students how many animals, plants, and fungi they found pictured on each poster. Call on each group to point out and identify some of the living things on each poster until all those shown are identified. (Write a master list for each poster on the board.) Compare the lists. Which animals were found only in alpine tundra? (Marmots, pikas, mountain goats, Dall sheep, water pipits, and horned larks). Which were found only in lowland tundra? (Loons, geese, eiders, phalaropes.) Question students as to why these differences in living things occur. Encourage students to think about where the animals live and whether or not the necessary habitat is found in both types of tundra. (Rocky slopes and cliffs needed by these alpine animals are not found in lowland tundra, and the ponds and wetlands needed by geese, loons, etc., are not found in alpine tundra.) Do students recognize that differences in the non-living environments cause differences in the living things present?

Evaluation:

Students complete Worksheets 2a and 2b.

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Pika Tag....................................SCIENCE, PHYSICAL EDUCATION
....INDOORS/OUTDOORS

OBJECTIVES: Students will become more familiar with a tundra animal, the pika, while playing an active game.
MATERIALS: large playing area, different color vests or tags to identify pikas, 1 hawk, and 1 weasel, cards or other markers to represent food, a timer
PROCEDURE:
1.BACKGROUND: Show studentsa picture of a pika (from poster). Explain that pikas are small animals related to hares and rabbits. They live in rock scree slopes of alpine tundra. Pikas must gather food every summer and dry it in the sun to have enough food to live through winter. They have several predators, but the most important ones are hawks and weasels. Pikas have an interesting habit--they call out "Myaaaa!" (like a goat bleat) whenever they see a hawk, but they are quiet if they see a weasel. Explain that the class is going to play Pika Tag--a game about the pika and its predators. Have 15-20 students join hands and form a large circle. Then draw a line to show a small inner circle (3-5 feet in diameter). Select 2 students to represent predators; the remainder will be pikas. Scatter food cards inside the perimeter of the outer circle. Then explain the rules.

PIKAS--The center circle represents the pikas' rock tunnels. Each pika must venture out of its tunnels to gather and dry food for winter. Each pika must go out to the edge of the outer circle to pick up food cards, bring these back to the edge of the inner circle and place them in a pile to" dry in the sun". Pikas are only allowed to pick up one food card at a time. Once they have gathered and dried 5 food cards, they must carry their food into their tunnels. When all their food is safely in the burrow, they may remain inside and stay safe from the hawk. They must remain alert for the weasel and stoop down if it appears, however.

Pikas are vulnerable to weasels in the open and in burrows, but they can escape by hiding or stooping down. If a pika cries out when he/she sees a weasel, then the weasel may capture him/her, even if he/she stoops down. (A call gives away a hiding pika.)

Pikas must give an alarm call when they see a hawk, and then run into their tunnels (the inner circle) to safety. Pikas should run for their tunnels whenever they hear an alarm call reporting that the hawk is around. The hawk may capture a pika even if he/she is stooping down. Hawks have sharp eyes.

HAWK--The hawk player remains outside the outer circle until he/she sees a vulnerable pika. Then, the hawk may go inside the outer circle and try to catch that pika--or any other unwary one. The hawk may not go inside the inner circle, however. A pika can escape the hawk by running into a tunnel (the inner circle), but not in any other way. After catching a pika, the hawk must run around the outer circle once before re-entering to catch another.
WEASEL--The weasel player catches prey by being sneaky. It quietly sneaks into the pika colony, and even into the tunnels. A weasel can catch any unwary pika inside or outside the burrows, unless the pika stoops down to hide before being tagged. A weasel may also catch a pika that calls out when it sees the weasel. After catching a pika, the weasel must run around the outer circle once before re-entering to catch another.

When a weasel or a hawk catches a pika, the pika is out of the game, gives the predator his or her tag, and joins the outer circle. The game should be timed and ended after 5-10 minutes. The winners of the game are any pikas that get 5 food markers and are not caught by a predator, and the predator that catches the most pikas. Play additional rounds so that all students eventually get to play.
A FURTHER NOTE: Pika players may try to steal food cards from their neighbors' haypiles. Although it is easiest to make this against the rules of the game, it is in fact a normal behavior for pikas. Individual pikas must be constantly on guard to prevent their hay from being stolen. They vigorously chase away possible thieves and spend a lot of time guarding their haypiles. If you want to allow stealing so that the game is more realistic, restrict players to stealing no more than one card at a time, and require that if a pika is caught in the act of stealing, the thief must immediately forfeit the stolen food card to its rightful owner. (The end result of stealing is usually that fewer pikas escape predators--they spend too much time watching other pikas and fail to notice the weasel or hawk.)

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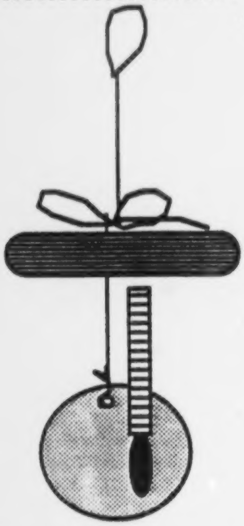
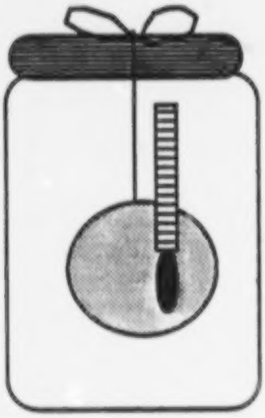
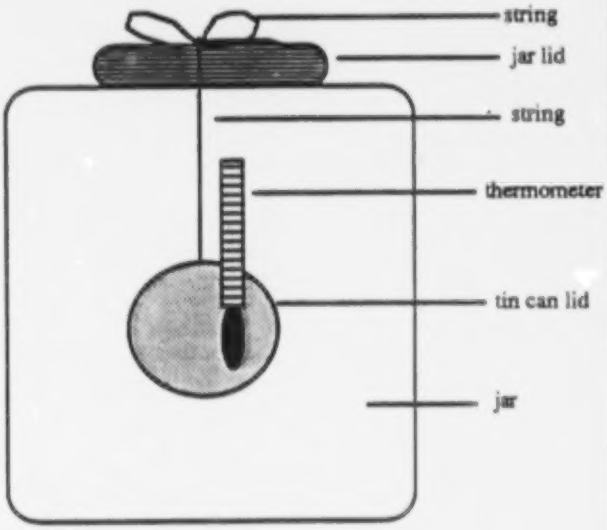
The Atmosphere Blanket..Science
....Indoors/Outdoors



Prepare 3 of the above. Suspend a tin can lid from a jar lid with string. Tape a small thermometer to the metal.



Place one inside a small jar. Close the lid tightly.



Place one inside a large jar. Close the lid tightly.

OBJECTIVES: Students will understand that the atmosphere acts like a blanket around the earth and will understand that mountaintops are cold because the "atmosphere blanket" covering them is not as thick.

MATERIALS: Balloon, 1 large and 1 small glass jar with large mouths and lids, 1 extra jar lid, string, 3 small thermometers, tape, 3 tops from tin cans.

PROCEDURE:

1. DISCUSS THE CONCEPTS OF AIR AND ATMOSPHERE. Ask students to breathe in and out, then ask them what they were breathing. Ask them what "air" is. They are likely to say "it's nothing". Ask someone to blow up a balloon. Then ask students how nothing can take up space inside the balloon. They should begin to grasp that air is made up of something we can't see.

2. CAN AIR KEEP US WARM? Ask students to imagine having a coat made out of air. Could it keep them warm? Take a survey--how many think it would, how many think it wouldn't? Suggest that the class do an experiment to find out whether air can keep something warm. Set up the jars as shown in the diagram above. Have students record the temperatures of the metal inside each jar. Then, place all the jars outside. Have students check the thermometers every 5-10 minutes. Which items cooled the fastest? Why did those in the big jars stay warm longer? (Students should conclude that air can keep things warm.)

3. DISCUSS THE EARTH'S ATMOSPHERE: Explain to students that the earth is surrounded by a blanket of air called the atmosphere. Visually convey the atmosphere concept by wrapping a thin layer of cotton around a globe. Show how mountains stick up into the atmosphere, so that the blanket of air over them is not as thick. (Mountains stick up near the edge of the first layer of the atmosphere (the troposphere) into the stratosphere which has an air temperature of -50° C at its lower edge.) Have students think about their toes sticking out from under a blanket. Ask them why they think tundra occurs on mountaintops--even near the equator. (They may need to know that the outer atmosphere and space are very cold.)

EXTENSION: Investigate the value of air as an insulator further. Bunny boots, down coats, and air mattresses are ways that humans use air as insulation. Birds and mammals keep warm not because of the insulation provided by feathers and fur, but by the insulation provided by the air the feathers and fur trap.

Alaska Wildlife Week Unit 6. © 1988 Alaska Dept. Fish and Game

TUNDRA RELAYS...................
........Physical Education / Science
....................Indoors / Outdoors

OBJECTIVES: Students will become more familiar with tundra organisms (or words) while practicing teamwork and physical education skills.
MATERIALS: Tundra Wildlife Cards, laminated and numbered with the organism names cut off or hidden (or see Variations); large open area; blackboard or large writing tablet with chalk or felt pen; physical education equipment as desired (see Variations)
PROCEDURE: Divide the class into relay teams of 4-6 students. Have each team stand in a separate line at one end of the playing area Spread the wildlife cards (prepared as described under Materials) on the floor or ground at the other end of the playing area. Write the names of 4-6 tundra organisms (depending on the number of students per team) on a blackboard or large chart. Explain to students that the objective of the relay is for each team to match the animal names to the correct pictures (cards). Each member of the team will have a chance to run to the other end of the playing area and pick up any card that they think shows one of the listed organisms. They must bring it back to their team for an OK. If the team agrees it is one of the animals on the list, they should write down the number on the card. The next player must then return the card to the pile and bring back another. Only one team member may leave the group at a time, and each student may only be a runner when it is his/her turn (he/she is at the front of his/her team's line.) No student may bring back more than one card, and the next relay runner may not leave without taking the card the former player retrieved. The first team to figure out the matching number for all 4-6 organisms yells out "Tundra! The instructor checks the team's answers; if they have made all correct matches they win 10 points for that round. If they have made an incorrect match, they lose 2 points for each incorrect answer. The round then resumes until one team gets the correct set of numbers.

VARIATIONS: Relay runners practice a physical education skill when travelling between their team and the card pile--e.g. dribbling, tumbling, skipping, climbing a rope, etc.

Instead of using the tundra wildlife cards, use photos of the animals; or use selected tundra glossary words and definitions, instead of animal names and pictures.

Wildlife Upset.........................
...............Science / Language Arts
.....................Indoors/Outdoors

OBJECTIVES: Students will become more familiar with tundra wildlife, while practicing listening skills.
MATERIALS: Tundra Wildlife Cards, masking tape
PROCEDURE: Tape a wildlife card to the shirt of each student in the class. Sit the class in a circle on the floor, or you may have them sit in their chairs. Choose one student to be "It." Have the remaining students sit close together so there are no empty spaces between them. (If playing with chairs, place books on all the empty seats.) The It player comes to the front of the room or middle of the circle. He/she calls out the names of two kinds of tundra wildlife. The two students with the cards showing those animals must exchange seats. If the It player can get to one of the seats first, the displaced player becomes the new "It." If any "It" player is unable to get a seat after two tries, they may call out the names of three players. Also, any player may call out "Wildlife Upset." On this signal all players must change seats.

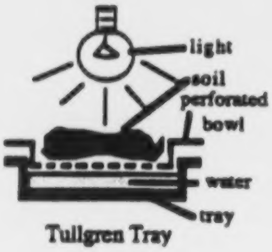
TUNDRA PEOPLE AND ENVIRONMENTS.................................
INDOORS...SOCIAL STUDIES

OBJECTIVES: Students will recognize that tundra environments occur around the world and will become familiar with the countries, environments, and lifestyles found in the tundra regions of the northern hemisphere.
MATERIALS: overhead projector, butcher paper, World Almanac, and a world atlas or maps of the world showing the distribution of tundra and the locations of countries and major cities, encyclopedias.
SKILLS: map-reading, geography, use of encyclopedia, atlas, and almanac; awareness of the similarities in the environments and cultures of people living in the north throughout the world.
PROCEDURE:
1. PREPARE A MAP MURAL–Use the overhead projector to make a large scale map of the northern hemisphere showing the boundaries of the continents and political boundries of countries, but do not label these.
2. STUDENTS COLOR IN TUNDRA REGIONS OF THE MAP: Have students refer to a map showing those portions of the earth that have tundra and help them decide which areas of the mural map are tundra and which are covered by ice and water. Have them color tundra areas yellow, ice areas white, and the water areas blue. They might also color forested areas green. (If desired, have students locate and color both alpine and lowland tundra areas. Alpine tundra occurs on the tops of all high mountain ranges.)
3. ASK STUDENTS TO ADD THE NAMES OF ALL THE COUNTRIES WITH TUNDRA ENVIRONMENTS. Give students the following list of countries and cities. (Norway, Iceland, Finland, Sweden, Greenland, Great Britain, Poland, Scandinavia, Canada (Yukon Territory, Newfoundland, Northwest Territory), Soviet Union (Siberia), Nordkapp, Longyearbyen, Spitsbergen, Murmansk, Tromso, Vardo, Stockholm, Helsinki, Inuvik, Yellowknife, Barrow, Nome, Petropavlovsk, Warsaw, Novaya Zemlya, Svalbard, Bergen, Reykavik, Thule.) Ask students to find out which of these contain or occur in lowland tundra. Ask students to find and label all these on the wall map. Discuss which countries have the most tundra and which have the least. Ask students whether they think the tundra in those other countries is similar to Alaskan tundra. Would it have the same plants and animals? Would the people live similar lifestyles?

Have students use the encyclopedia and world almanac to find the answers. Divide the class into groups and assign each group to research the lives and tundra of a specific country. (Or assign individual students.) Ask each group to draw pictures, write a report, or prepare an oral report on the tundra, wildlife, and lifestyles of people in the assigned country or city. (Those who research a country that includes both forest and tundra need only describe the environment, animals, and lifestyles of the tundra region.) After students complete the assignment, have the class compare and discuss their findings. Do people who live in similar environments have similar lifestyles?

EXTENSION: Have students choose a country that contains tundra that they would like to learn more about. Have students write to another class, a newspaper, or to pen pals in that country. Encourage students to describe Alaskan tundra and their Alaskan lifestyle to their readers and ask the readers questions about the tundra and lifestyles in their countries. Students might send photographs or artwork illustrating Alaska's tundra environments. With a little luck, the class might receive some fascinating responses from other northerners of the world.

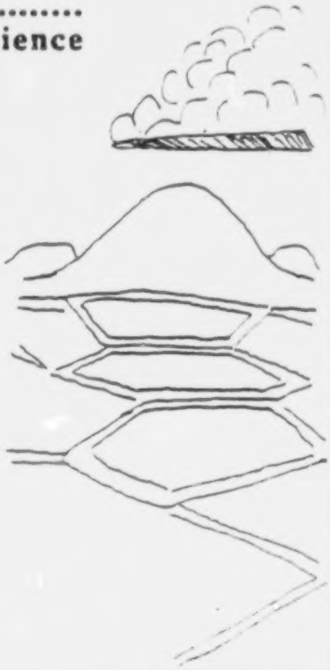
Life in the Tundra Soil......................
Indoors......................Math / Science



OBJECTIVES: Students will become aware of the number and variety of invertebrate animals that occur in tundra soil.
MATERIALS: A sample of tundra soil; glass jar; perforated bowl, tray with water, incandescent light; award for contest; hand lenses or dissecting scope
SKILLS: estimation, measuring
PROCEDURE:
1. Collect a sample of the top 2-5 inches of tundra soil. Place this in a glass jar and place the jar in a conspicuous place in the classroom. Ask students to guess how many animals are in the soil sample. Each student may enter 1 guess; the student who gets closest will receive an award.
2. After all students have made guesses, force the invertebrates out of the soil sample using the Tulgren Tray shown at right. (Allow 24 hours to see the results.) Then have students help count the number of organisms that tumbled out. (Have students use a dissecting scope or hand lenses to look at the animals closely. Can students identify any of them? They should find mites and springtails at least.)
Award the student whose guess was closest to the number of organisms found. Discuss the number of invertebrate animals that scientists have found in samples of tundra soil (see background information in the Tundra Wildlife Cards section of this packet).

Tundra Topography..
Indoors...Art /Science

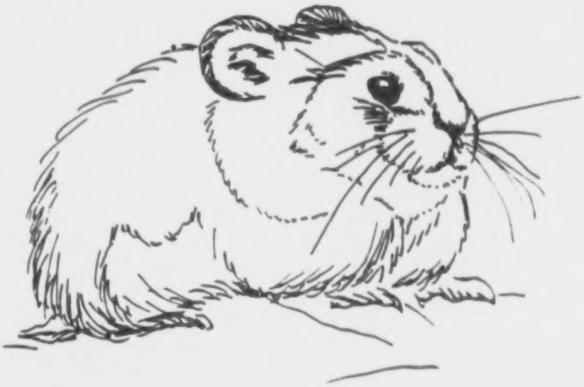
OBJECTIVES: Students will demonstrate their awareness of the topographical differences between alpine and lowland tundra by making clay models of both.
SKILLS: cooperation; ART: sculpture, painting
MATERIALS: modeling clay or play dough, paint brushes, paint, cotton, straw, or other art materials as needed to enhance the models.
PROCEDURE:
Divide the class into groups and ask each group to make a model of alpine or lowland tundra. Specify that each group should try to show all the features that are unique to the tundra type they are modeling. Encourage students to refer to the posters as well as books and other reference materials when planning their model. Each group should make a list of the things they want to include in their model, so you can check it over and help them notice additional things to include. Ask students to divide up the task of making the model so that each student in the group has a specific task. (For example, one student might be in charge of making the snow, another in charge of rocks, another in charge of water, another in charge of animals, etc.) (Encourage students to include all the topographic features described in the permafrost features section of the Tundra Wildlife Cards Supplement)



The Adventures of a Pika...
Indoors..Language Arts

OBJECTIVES: Students will increase their awareness of alpine tundra and alpine tundra wildlife by writing a short story about a tundra animal.
SKILLS: LANGUAGE ARTS--writing, creativity, use of the library
MATERIALS: reference books about alpine tundra and tundra animals, pencil and paper
PROCEDURE:
1. Use the story of Dicrostonyx to review the elements of a story with students. Help them identify the main character, the setting, and the plot. Then ask students to write a similar story about an alpine tundra animal. (To make sure students understand the assignment, ask them what will be the main characters in their stories. (Alpine tundra animals.) What will be the setting? (Alpine tundra.) Encourage students to develop the character and the setting. Discuss ways of doing this. What animal is the main character? Is it male or female? How old is it? What characterisitics does it have? (It runs fast, thinks quickly, or knows how to hide.) What about the setting--is it winter or summer, day or night? Discuss the term "plot" and suggest some possible plots (i.e. adventures) for a story. (hare escapes predators, caribou migrates, pika prepares for winter)

Encourage students to write realistic stories. Discuss the term "realistic" carefully. Students should understand that in a realistic story, the animals behave like real animals (by not talking or wearing clothes, by eating the appropriate foods, by living in the appropriate habitat (not in human houses), and by doing appropriate activities). (For help with this concept, refer to the Project Wild activtity called"And the Wolf Wore Shoes".) To write a realistic story, students will need to know something about the animal they choose as the main character for their story and something about the environment in which it lives. Encourage students to imagine they are the animal they are writing about and imagine what that animal might see, hear, smell, and feel. This will help them imagine things to write about.



Have students follow these steps to write their story:
1. Choose a tundra animal to be the main character of your story. Research the facts about the animal and its life and think these over.
2. Make up a plot about a day, month, or year in the life of this animal. Quickly write your story down. Don't worry about spelling and punctuation at first.
3. Read the story out loud to another student or a parent. Discuss ways that it could be improved.
4. Rewrite the story incorporating the necessary changes. Check and correct spelling and punctuation.
5. If desired, draw an illustration of the main character or one event in the story.

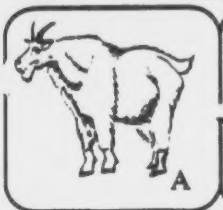
Alaska Wildlife Week Unit 6. Alaska's Living Tundra © ADF&G 1988

Upper Elementary

Worksheet 2a.
Tundra Animals

Name______________________________

Match the name of each animal to the letter next to its picture. Then answer the last three questions. If all your answers are correct, you can solve the puzzle at the bottom of the page by replacing each number with its matching letter. The secret phrase describes you!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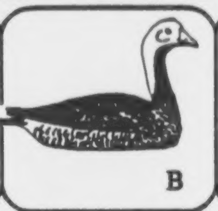
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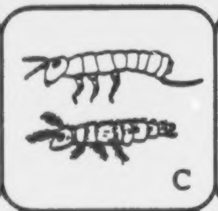
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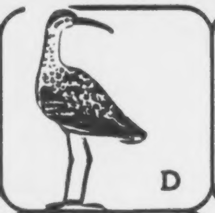
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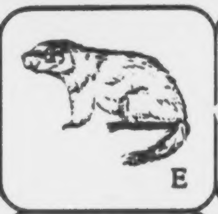
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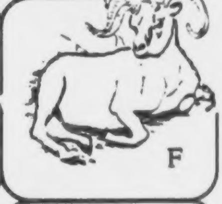
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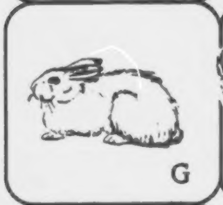
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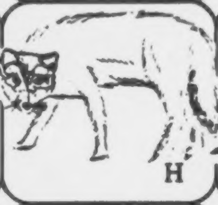
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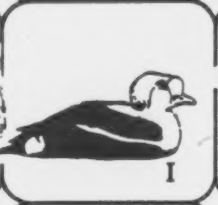
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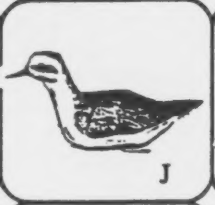
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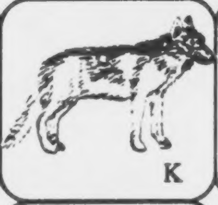
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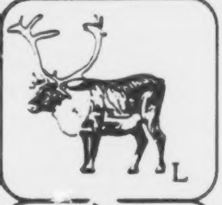
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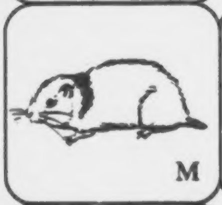
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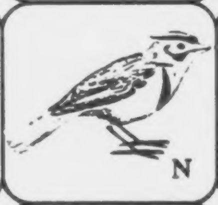
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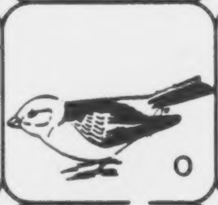
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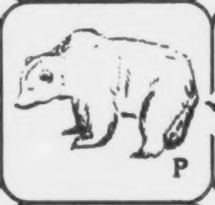
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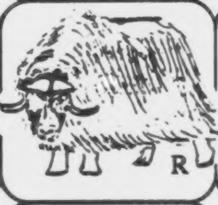
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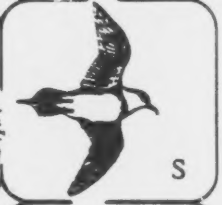
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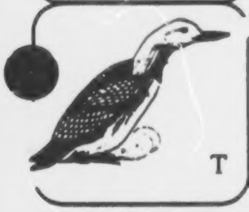
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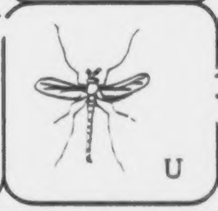
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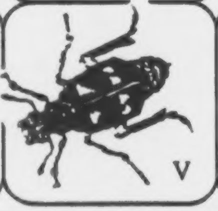
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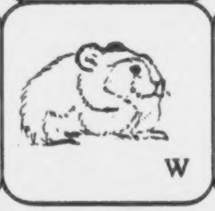
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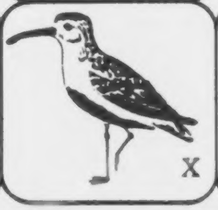
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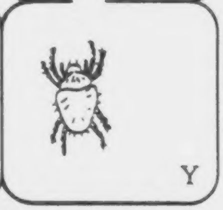
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_____ 1. Dall Sheep
_____ 2. Tundra Hare
_____ 3. Whimbrel
_____ 4. Marmot
_____ 5. Mountain Goat
_____ 6. Arctic Loon
_____ 7. Muskoxen
_____ 8. Carrion Beetle
_____ 9. Parasitic Jaeger

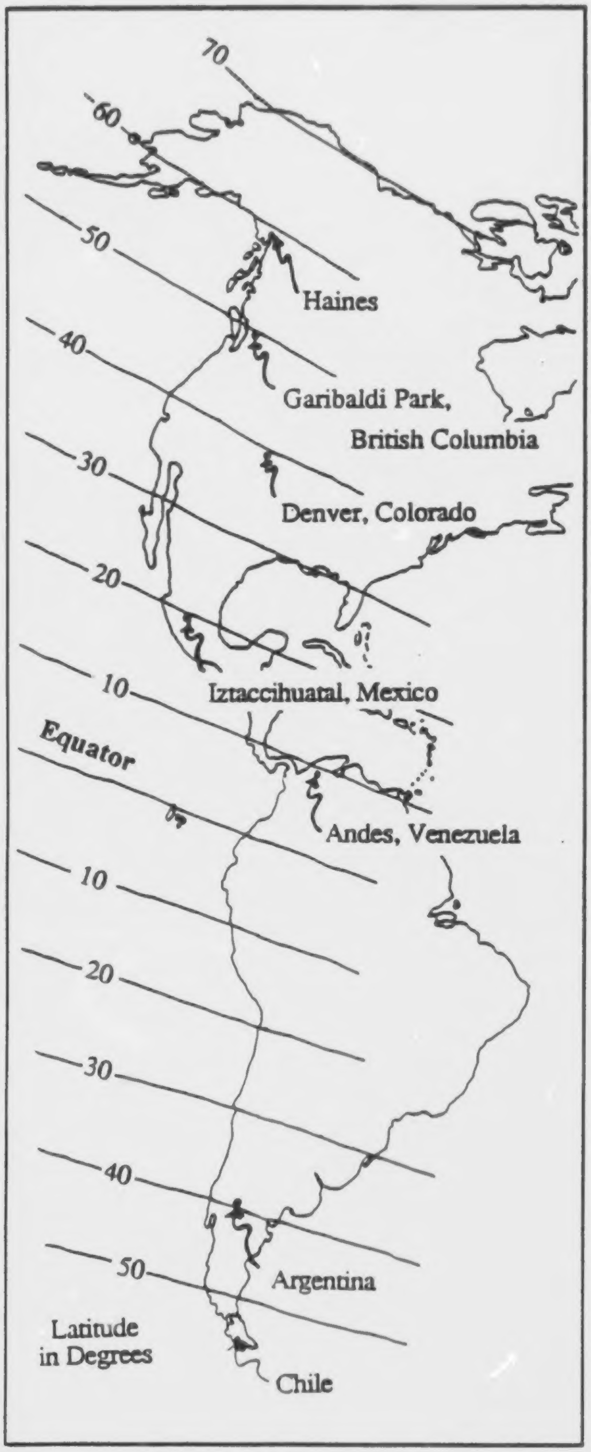
_____ 10. Cranefly
_____ 11. Emperor Goose
_____ 12. Snow Bunting
_____ 13. Horned Lark
_____
_____ 14. Which of these animals occurs only in alpine tundra? W J M
_____ 15. Which of these animals occurs only in lowland tundra? I K C
_____ 16. Which of these animals occur in both alpine and lowland tundra?
A L W

5 2 12 12 3 12 11 9 4 7 8 4 7 12 1

6 10 13 3 7 5 14 15 16 3 16 15 1 4

Worksheet 2b. Changes in Latitude

Name___________________________


70
60
50
40
30
20
10
Equator
10
20
30
40
50
Haines
Garibaldi Park, British Columbia
Denver, Colorado
Iztaccihuatal, Mexico
Andes, Venezuela
Argentina
Chile
Latitude in Degrees

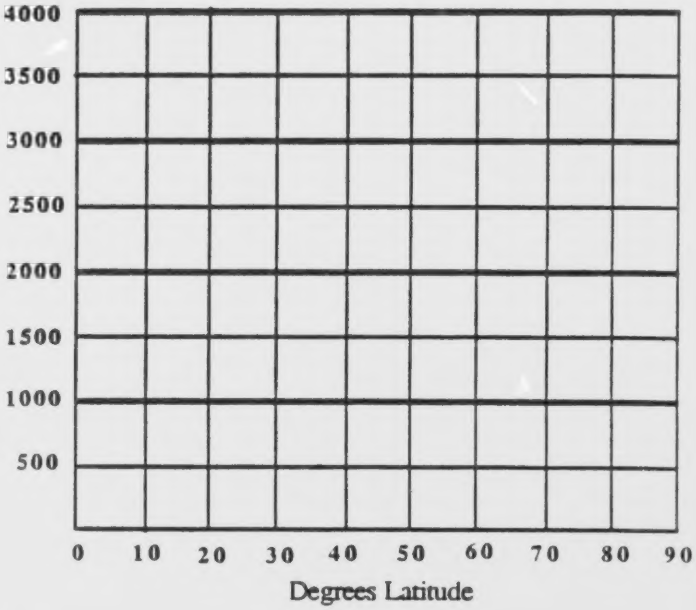
Treeline is the environmental boundry between forest and tundra. A treeline occurs at the southern edge of lowland tundra. Other treelines occur on mountaintops around the world, at the lower edge of alpine tundra. Use the following data and the map above to make a graph comparing latitude and the elevation at which treeline occurs on mountain slopes.

Location	Treeline Elevation in Feet
Denver, Colorado	3350
Haines, Alaska	900
Iztaccihuatal, Mexico	3950
Garibaldi Park, British Columbia	2150
Andes, Venezuela	4200
Andina de Neuguen, Argentina	1650
Southern Chile	4900

Based on your graph, use the following words to describe how latitude and the elevation of treeline are related:

increases decreases higher
lower increase decrease

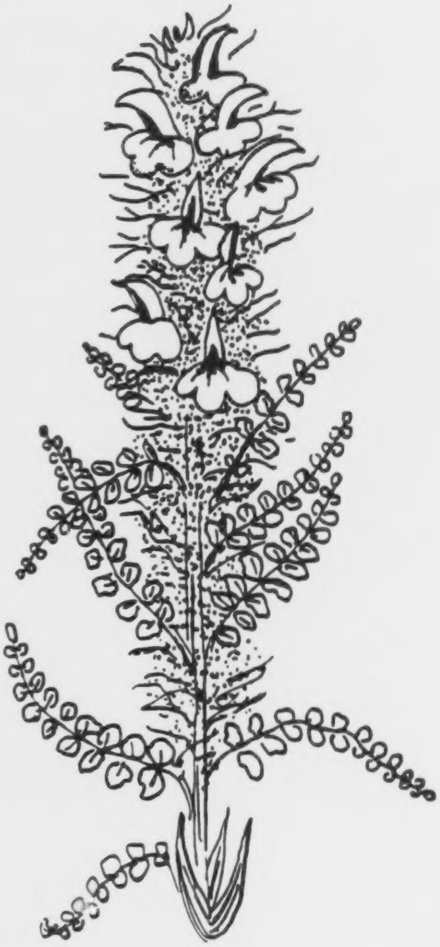
1. As the latitude _____________, the elevation at which treeline occurs _____________.
2. In other words, alpine tundra occurs at _________ elevations at high latitudes.
3. A 10 degree increase in latitude results in an approximate ______ feet ___________ in the elevation of treeline.
4. Locate your town on the map, and figure out the elevation of treeline near you. Record it here: ___________
5. At what latitude do you think lowland tundra begins? _________



Lesson 3.

Vocabulary:

adaptation, antifreeze, dormancy, hibernation, migration, staging



Objectives:

Students will be able to define the term adaptation and describe some of the adaptations of tundra plants and animals.

Background:

Biologists call the physical, physiological, and behavioral traits that help an organism survive in a particular environment, "adaptations". Organisms that live in tundra environments must have adaptations to help them survive and raise young despite the periodic severe cold, persistant winds, short growing season and other difficulties posed by this severe environment.

The following pages provide some specific examples of the amazing adaptations that allow specific living things to live and flourish in tundra ecosystems. (These pages may be used as student reading material, or for bulletin board displays.)

Alaska Wildlife Week 1988. Unit 6. Alaska's Tundra. © 1987 ADF&G

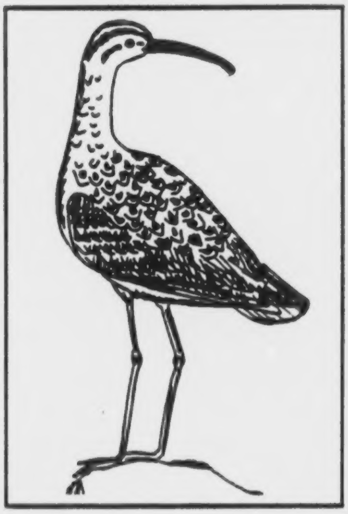
Migration is an adaptation for avoiding the severe winter conditions of tundra environments.

Many living things are able to live seasonally in tundra environments by avoiding the period of severe cold and strong winds by migrating to an environment with less harsh conditions. The seasonal gatherings and movements of large numbers of animals into and out of tundra environments are among the most spectacular natural events in the world. Each spring, huge flocks of shorebirds and waterfowl rush toward the tundra. Areas that were barren of life in winter can come alive with the movements and calls of arriving migrants almost overnight. These birds spread out over the tundra expanses to nest. Only in late summer and fall, when these avian migrants and their young gather together before hurrying south, is the surprising productivity of the tundra expanses revealed. The gathering places of migrants, called staging areas, occur in the same places year after year. Usually they are in locations that provide abundant food, so the migrants can fuel-up for their long-distance travels. Some migrant birds nearly double their weight with layers of fat before leaving.

Many birds travel thousands of miles to wintering areas in Central and South America or Polynesia. The arctic tern migrates 10,000 miles (16,094 km) to winter in Antarctica. Some birds, like ptarmigan, migrate relatively short distances. They move south out of arctic tundra areas, and downslope from high alpine areas to low alpine or forested areas.

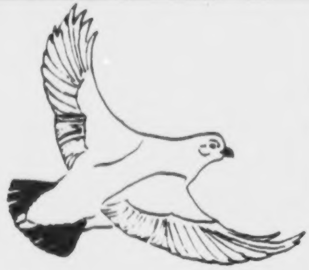
The migration of caribou from tundra areas to more southern forest environments is one of the best known examples of migration by a mammal. Their annual movements may, in part, be an adaptation for avoiding the severe winter conditions in tundra. The crusty snow pack that covers many tundra areas in winter makes it difficult for caribou to uncover food. However, some caribou do not migrate, but instead remain in tundra year-round.

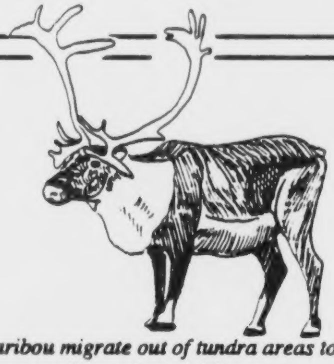
Many tundra fish also migrate. In fall, they move into places where the water does not freeze solidly in winter. Deep lakes, deep channels in large rivers, and spring-fed streams are important over-wintering areas for tundra fish.



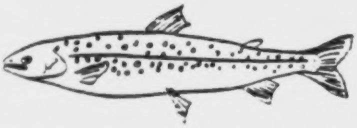
Whimbrels nest in tundra but migrate to spend the winter on the Pacific coast from California to Chile. Most shorebirds migrate thousands of miles to southern wintering areas.

Ptarmigan migrate out of the northernmost tundra regions to winter in the alpine tundra and forests of central Alaska.



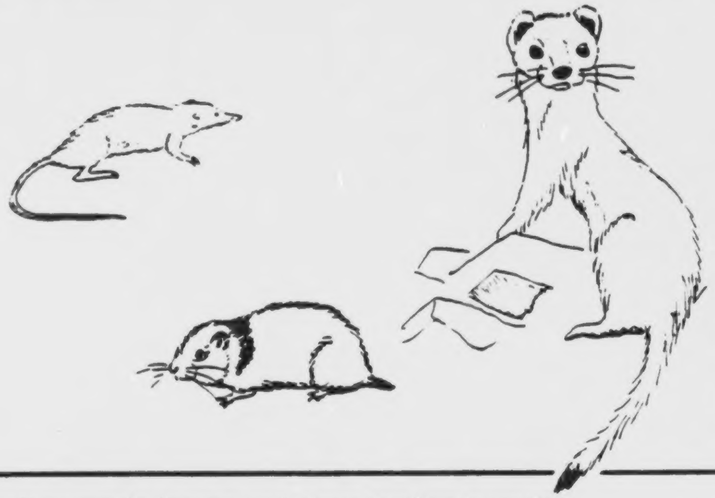


Caribou migrate out of tundra areas to winter in more southern taiga and forests.



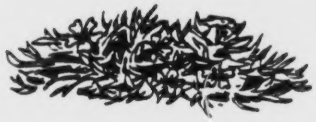
Tundra fish, such as arctic char, migrate to places where some water remains liquid throughout winter.

Many living things remain on the tundra year-round, but avoid the severe winds and cold.



Lemmings, voles, shrews, weasels, arctic ground squirrels, insects and most plants survive the winter winds and cold by living beneath the snow. Temperatures under a blanket of deep, soft snow are usually 20° F (34° C) warmer than the air temperature above the snow. However, in tundra areas with crusty, windblown snow, the under snow temperature may drop to -31°F (-35° C).

The small mammals, insects, and plants that live in tundra cannot make long distance journeys to avoid the severe winter conditions of tundra. Many of these winter residents avoid the severest winter conditions by remaining beneath the snow. For example, lemmings tend to concentrate in areas where the snowpack is greatest. The snow shelters them from the wind. It also offers some protection from the cold of winter. However, the dense, wind-packed snow of arctic tundra is a poor insulator and provides only limited protection from the cold. (In contrast, where the snow is protected from wind, it is deeper and less dense and provides much better insulation.)



Air temperatures near the ground are warmer and winds are slower near the ground surface. Many tundra plants, such as moss campion, grow in low, flat mats or cushions to take advantage of these milder conditions.

Some animals, like the arctic ground squirrel, move underground for winter. Soil, like snow, provides insulation against the cold and wind. Many plants have a similar adaptation; their above ground parts die back each winter, but their main growth and energy storage is in their underground roots, which, sheltered by the soil and snow, survive the winter cold and winds.

Environmental conditions on the tundra are most severe during winter, but cool temperatures and strong winds during summer also pose problems to living things. The adaptations of many living things enable them to avoid the cold and wind year-round. For example, many tundra plants are small and grow in flattened, cushion-like forms. Due to friction, the wind speed an inch or two above the ground is much less than the wind speed farther above the ground. The air is also warmer near the ground than above it because soil absorbs and radiates heat from the sun. Many kinds of insects live their entire lives in the shelter of ground plants, thus avoiding the most severe cold and wind of the tundra. Wingless forms of many insect groups are most common in tundra environments. Arctic ground squirrels and brown bears select south-facing slopes in which to dig their underground dens. These sites are warmer than north-facing slopes during fall and spring.

Wingless insects are common in tundra environments. They spend their entire lives in the shelter of soil, mosses, or other plants.

Some tundra organisms make antifreezes.

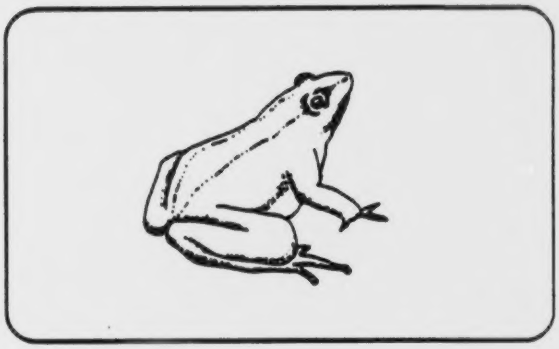
Most people have heard of the antifreeze which we add to the water in our vehicles during winter to prevent the water from freezing. This antifreeze is made up of ethylene glycol, a fluid which freezes at a lower temperature than water. By mixing it with water, we can lower the freezing temperature of the water. Most living things are made up of 70% water. When water freezes, it expands and forms ice crystals. If this occurs in a living organism, the cells are damaged. Repeated freezing and thawing are particularly destructive of living tissue. Yet repeated freezing and thawing temperatures are characteristic of the milder summer season in tundra environments.

Some organisms have overcome this problem in essentially the same way that we protect the water in our vehicles. They produce chemicals that lower the freezing temperature of cell fluids. These antifreezes prevent the formation of large ice crystals within the cells even at very low temperatures.

Because of the antifreezes in their blood, wood frogs can survive temperatures of 21°F (-6°C). Most arctic insects produce glycerol, which is an effective antifreeze. If cooled slowly, certain arctic insects can withstand tempertures of -76°F (- 60 °C).

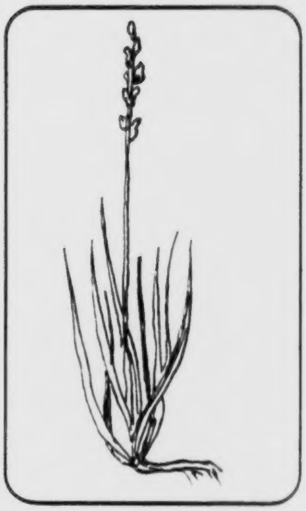
Some tundra fish also have antifreezes. Alaska blackfish can survive temperatures as low as 4° F (-20° C), as long as their bodies are not completely frozen.

Plants need antifreezes not only to prevent freezing, but also so they can make enough food to survive. The process of photosynthesis requires water, so many plants cannot function if the temperature is below 32° F (0°C), the freezing point of water. But air temperatures in tundra environments often drop below zero in spring, fall, and even summer. Many tundra plants, like Dupontia fischerii, a tundra grass, are able to photosynthesize at temperatures of 25°F, (-4°C). because antifreezes which they produce keeps cell fluids liquid even at this low temperatures.



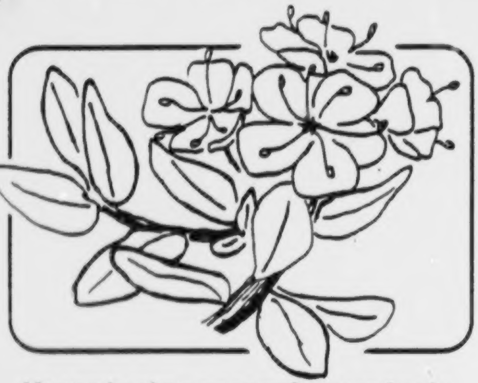
Wood frogs can withstand temperatures of 21 F (-4C).

Some tundra insects can withstand temperatures of - 76 °F (-60°C).

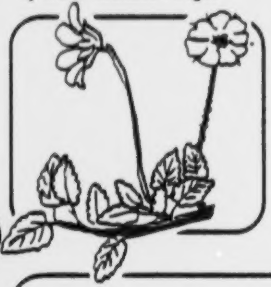


Many tundra plants, like Dupontia fischeri can photosynthesize sugars at temperatures below the freezing point of water.

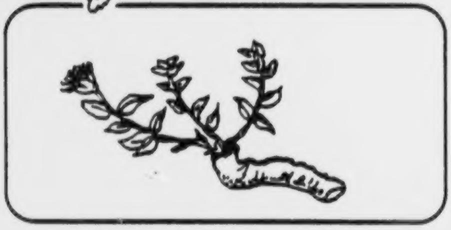
Tundra plants have adaptations that allow them to survive even though they can only be active during 3-4 months of the year.



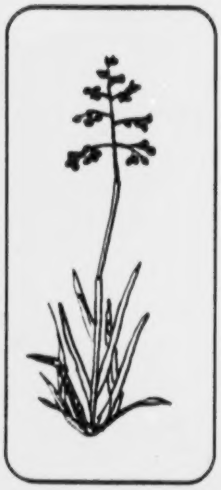
Most tundra plants are several years or decades old. The age of some woody tundra plants has been estimated at 200-300 years base on a count of thier annual rings.



Tundra flowers bloom from buds that are 1-2 years old.



Many tundra plants reproduce by rootstocks or runners.



The seeds of Poa alpina germinate and grow while still nourished by the parent plant.

The short growing season of tundra environments poses a problem to most living things, and severely limits the productivity of tundra. All living things ultimately rely on plants (and other organisms) that are able to make food sugars by photosynthesis. Plants can only photosynthesize food if they have adequate supplies of sunlight, air, and liquid water. Tundra plants cannot grow during most of the year due to the low intensity of sunlight, snow cover, and temperatures below the freezing point of water.

Tundra plants have several adaptations that allow them to survive despite the short season. First, when conditions are right for photosynthesis, tundra plants can actually make food faster, and grow faster than plants adapted to other environments. They are well adapted to photosynthesize at low temperatures and low light intensities. This ability enables them to make better use of the short growing season, but the season is still too short and cold for most plants to grow very much. Most tundra plants require many years to grow the same amount that a plant in a milder environment grows in a single year.

Most tundra plants store sugars in their roots each summer, so that they can begin growing new leaves even before the snow over them melts away. This is advantageous because it allows them to begin photosynthesis as soon as they are exposed to sunlight in spring. Many tundra plants keep their leaves from year to year. These "evergreen" plants can also begin photosynthesis as soon as they are exposed to sunlight in spring.

Many tundra plants must grow for a decade or more before they have enough leaves to store up the energy required to form flower buds. Then, most require 1-3 years to develop the buds. Nearly all tundra flowers come from buds that are 1-2 years old. The fragile flower buds develop underground, or are enclosed by dead leaves, so they are well-insulated during the cold winters. When spring comes, the tundra can literally burst into bloom because the flower buds were formed in previous years.

Because tundra plants need so many years to develop from seed to flowering size, many plants reproduce by rootstocks or runners, instead of, or in addtion to seeds. The tiny plants that sprout from the rootstocks are identical to (or clones of) their parent. The "clone" plants are nourished by the parent plant, which has many leaves, until the clones have many leaves of their own. Some tundra plants, like the grass, Poa alpina, produce seeds that germinate and begin to develop while still attached to the parent. This is an advantage because the young plants that drop off the parent already have tiny leaves and can begin photosynthesis right away.

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The coloration of living things in the tundra are adaptations to their cold environment. Which is warmer, dark or light?

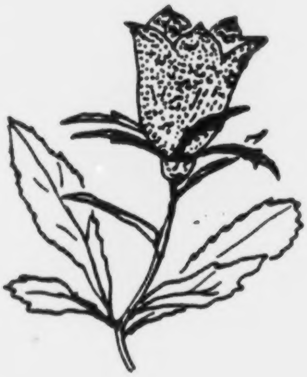
Dark colors absorb heat, while light colors reflect it. Thus, one might expect that organisms that live in cold tundra environments would be darker than organisms living in warmer environments. A study of flowering plants showed that the proportion of dark colored flowers is greater in the tundra than in warmer environments. Many tundra flowers are purple, blue, or yellow because these colors absorb more heat than white. Certain tundra insects are darker than related species that occur in warmer habitats. The value of dark color can be increased by an organism's behavior. For example, many butterflies bask in the sun with their dark wings spread wide to absorb heat.

Thus, among organisms whose temperatures are strongly influenced by the environment, dark colors can be an adaptation for survival in a cold environment.

However, the light coloration of arctic poppies (and other flowers) is an adaptation to the cold environment, too. The flowers of these plants are heliotropic, meaning they turn to face the sun. The shape of the light petals are such that they reflect sunlight toward the flower center where the seeds are produced. Several kinds of insects bask in the centers of these flowers, and benefit from the focused solar heat.

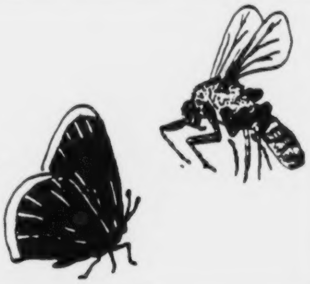
Many animals that maintain warm body temperatures (homeotherms), such as birds and mammals, have light, or white, feathers or fur. Their light coloration also may be an adaptation for staying warm. These animals generate their own heat, but lose heat when it radiates to their surroundings. Light colors radiate less heat than dark colors, so light fur and feathers actually may help warm-blooded tundra animals keep warm!

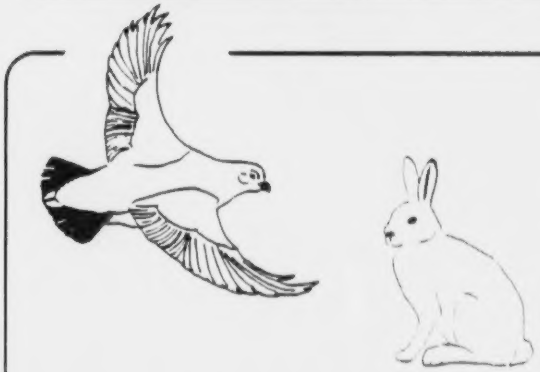
White fur and feathers also camoflauge animals in the snow. Thus white coloration may help collared lemmings, ptarmigan, and snow buntings.escape their predators, and help snowy owls, weasels, and arctic foxes sneak up on their prey.



More tundra plants have blue or purple flowers than plants in warmer environments.

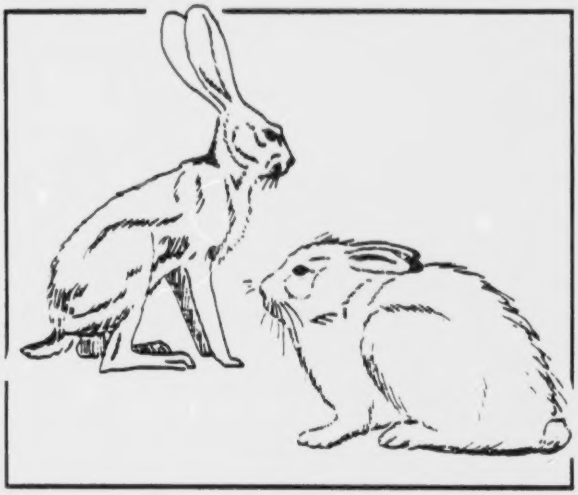
Most tundra insects are darker than related insects in warmer enviornments.



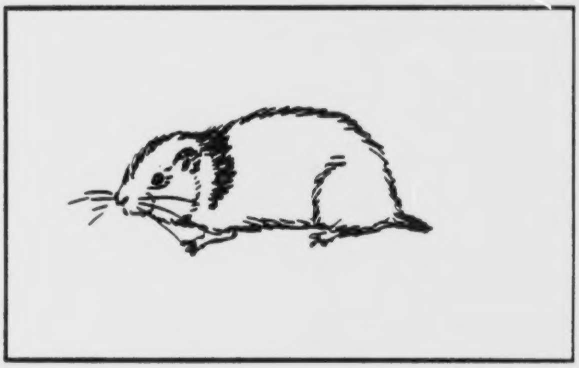


Many warm-blooded animals that live in tundra have white fur or feathers during winter.

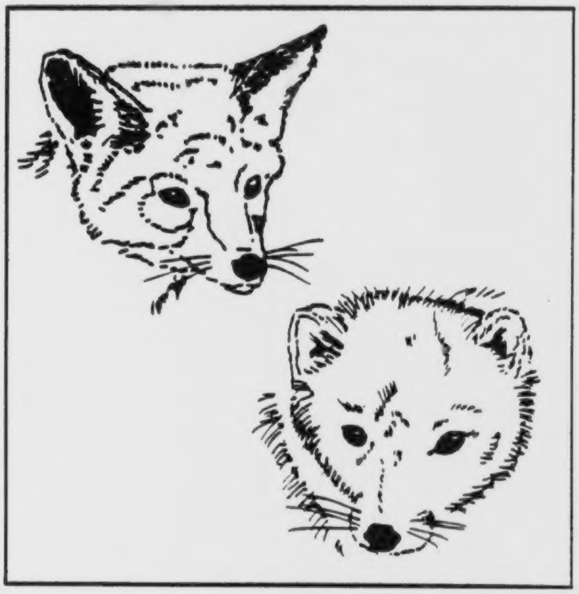
Large size and short appendages are adaptations that help tundra animals keep warm.



Tundra hares are larger and have shorter ears than hares that live in hot environments.



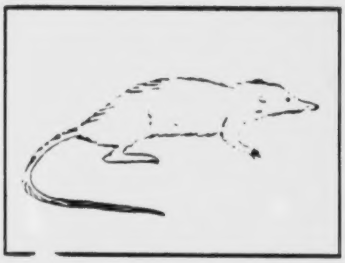
Lemmings are larger, and have smaller ears and tails than most other mouse-like animals.



Arctic foxes have shorter ears than desert kit foxes.

Biologists have noticed that many tundra birds and mammals are larger and have smaller appendages than similar species living in warmer environments. For example, tundra hares are among the largest hares and have shorter ears and legs than desert hares (called jackrabbits). Similarly, arctic foxes have shorter ears than desert kit foxes. Even lemmings, though small, are larger, and have smaller ears and tails than most other mouse-like animals. Large size and short appendages are adaptations that reduce heat loss and resist cold. The amount of heat lost increases as the proportion of surface area exposed to the environment increases. Since small animals have more surface relative to their weight than large animals, they lose heat more quickly. An animal with long legs, ears, or a tail has more surface area than an animal of the same size but with shorter appendages.

However, small size can also be an adaptation for survival on the tundra. Why? Because a small organism can survive on a smaller, total amount of food than a large organism (of the same species). Very small organisms can also live under the snow and avoid the most severe conditions of winter. Shrews, the smallest of all mammals, are able to live in tundra of arctic Alaska.



Small animals like shrews are able to keep warm despite their small size, in part because they can live under the snow.

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Food is scarce during the 8 months of winter, so tundra animals must have adaptations that help them survive with little food.

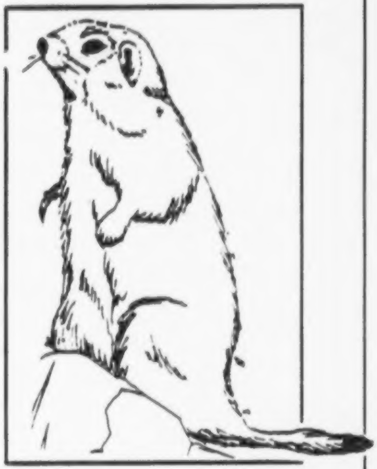
Plants, insects, and microscopic organisms simply cease functioning during winter. They do not move, grow, or breathe during the winter, so they have no needs for food. Birds, mammals, and fish cannot survive unless they continue to breathe, so they cannot become completely dormant.

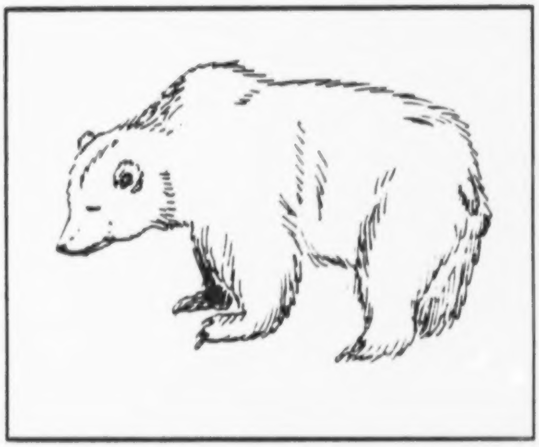
Some animals survive, not by ceasing to function, but by reducing their functions to the minimum needed for survival. For example, arctic ground squirrels and marmots hibernate. During the 7-8 months of winter, an arctic ground squirrel remains inactive, its heart beat is reduced from 200-400 to 7-10 beats per minute, its body temperature is reduced from 97 to 62 °F (36 to 17°C), and its breathes only 3 times each minute instead of 60 times per minute. While dormant, a ground squirrel uses 98 percent less energy than while awake. Brown bears also survive winter by becoming dormant; their heart rate is reduced from 50-60 to 20 beats per minute, but their body temperatures are not reduced, so scientists do not consider their dormancy a true hibernation.

Arctic ground squirrels, marmots, and brown bears must store enough energy during summer to maintain their body functions throughout their winter dormancy. All of these animals store the needed energy as layers of fat. A brown bear (in tundra habitat) that weighs 300 lbs (136 kg) in fall emerges from its den in spring weighing less than 200 lbs (91 kg), because it uses its fat (or energy reserves) while dormant.

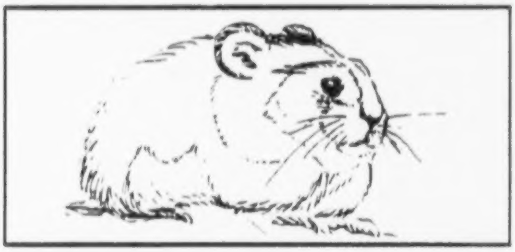
Many tundra animals are not dormant during winter, however. Lemmings, for example, remain active and even raise young during winter. They survive by feeding on the energy-rich buds, stem bases, and rhizomes of dormant plants. Pikas and singing voles remain active during winter too; they survive on food they stored for winter use. During summer, pikas busily gather and dry grasses in the sun, then store the hay in caches near their nests. Singing voles build large piles of grasses and other plants for winter food.

Humans may die if their body temperatures drop below 90° F (32° C) for even a short time, but arctic ground squirrels drop their normal 97 F (36° C) body temperature to only 62 F (17° C) during hibernation. This greatly reduces their needs for energy.





Brown bears only eat during 4-5 months of the year. Some may lose up to 30% of their body weight during winter when they must live off of the energy stored in their fat.



Pikas cut grasses and other plants then dry them in the sun during summer. They then store the dried hay underground as a winter food supply.

Introductory Activity 3.

Objective:

Students will recognize that the living things that occur in tundra have special traits and behaviors (i.e. adaptations) that enable them to survive in this environment.

Skills:

SCIENCE: comparing, predicting, inferring
LANGUAGE ARTS: reading, oral communication

Materials:

Adaptation Cards in the Tundra Wildlife Cards supplement to this packet, blackboard, chalk, masking tape.

Procedure:

SUMMARY: Students will use information about specific traits (or adaptations) of animals to determine which living things (pictured and described on the Adaptation Cards) live in tundra.

1. PREPARATION: Cut out and laminate the Adaptation Cards.

2. PASS OUT THE ADAPTATION CARDS: Divide the class into groups of 2 or more. Place at least 1 pair of adaptation cards (matching symbols) picture side down on a desk in front of each group (or place tape over the name of the animal and its environment to hide this information). Students should read the cards, but not turn them over. The groups should discuss the information provided on the cards and be prepared to place one card under a "Lives in A Tundra Environment" category, and the other in a "Lives in A Different Environment" category. They should also be able to explain why they placed the cards in the categories. (ALTERNATIVELY: If all students' reading skills are not adequate for the above task, you might place one good reader in each group, OR read the sets of cards aloud, and discuss the problem as a class instead of having student groups work independently.)

3. STUDENTS PLACE THEIR CARDS IN THE APPROPRIATE CATEGORY. Write two headings on the board: "Lives In A Tundra Environment", and "Lives In Some Other Environment." Then have one student from each group come up to the board, read their cards to the class, then place them in the categories their group decided upon. Have the class vote whether they agree or disagree with the placement. If they disagree, have the student describe the group's reasons for classifying the cards as they did, and have dissenters from the class explain their reasons for disagreeing. Then, turn the cards over to show the described animals or plants, and find out the correct placement. Tape the cards to the board under the appropriate categories. Repeat until each group has correctly placed their cards.

4. ASK STUDENTS WHAT SIMILARITIES THEY CAN FIND AMONG THE TUNDRA ORGANISMS. Students should recognize that all the organisms that live in tundra have traits that help them survive in the tundra environment. For example, many have traits that help them keep warm--e.g. long hair or dense feathers. Explain that traits that help an animal or plant survive in its environment are called "adaptations."

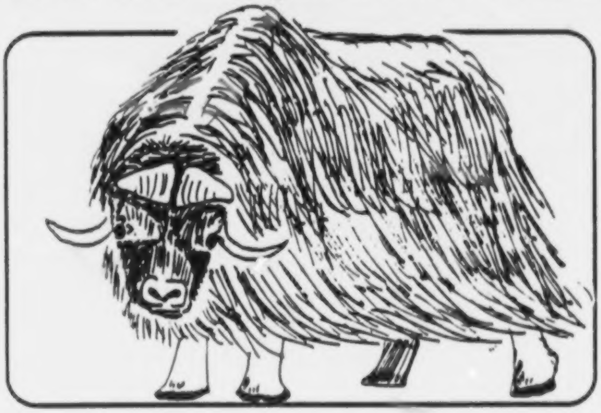
Use questions to help students realize that the living things found in other environments also have adaptations. Though not helpful for life in the tundra, the described trait of each living thing is helpful for life in the kind of environment in which it lives. Briefly discuss the adaptations to other environments which the living things under the "Other Environments" category have. (Living things that live in the desert have adaptations that help them survive heat; those that live in the ocean have adaptations for swimming and keeping warm in the water; those that live in forests have adaptations that help them take advantage of the food and cover provided by trees.)

EXTENSIONS: All of the Curriculum Integration Activities further develop the concept of adaptations and can be used for reinforcement or evaluation of student understanding.

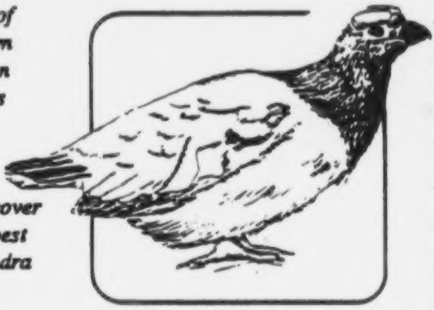
Evaluation:

Students complete Worksheet 3.

Most tundra organisms have insulation to help them stay warm.



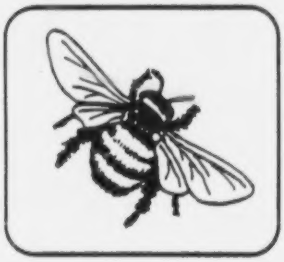
The long, dense fur of muskoxen helps them stay warm even when the air temperature is -40°F (-40° C).



Ptarmigan, whose feathery coats even cover their feet, have the best insulation of any tundra bird.

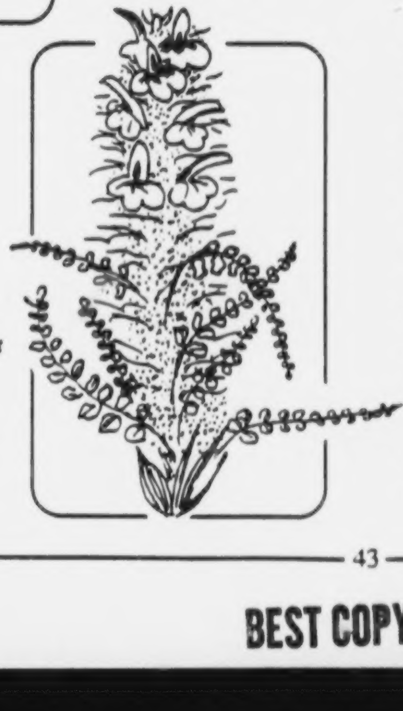
One of the most obvious adaptations for life in a cold environment is insulating feathers or fur. Most tundra birds and mammals actually have two coats. Their outer coats are made up of tough, coarse water-repellent feathers or guard hairs. Their inner coats are made up of soft, fluffy feathers or hairs that trap air. Ptarmigan can keep their body temperatures at 104° F (40°C), (without increasing their respiration rate) even at temperatures of -29° F (-34° C). Caribou and muskoxen have hollow hairs that are fatter at the tips than at the base. This shape helps the hair trap a layer of air next to the body. Trapped air provides excellant insulation.

Tundra bumblebees provide a fascinating example of the adaptive value of an insulative coat. Insects are cold-blooded or poikilothermic organisms, which means that their body temperatures are closely related to the temperature of their surroundings, and rise and decline accordingly. The chemical reactions necessary for movement do not occur at cold temperatures, so most insects can not move unless the temperature is above freezing. However, dense hair on the bodies of tundra bumblebees slows heat loss from their bodies to the air. Certain bumblebees "shiver" their flight muscles to generate heat. This heat is temporarily trapped within the bee's velvet coat. Certain bumblebees can keep their body temperatures 68-86°F (20-30° C) above air temperatures, and thus can easily be active when other insects are too cold to move.



Tundra bumblebees have dense velvet-like hair that helps them keep the heat released when they move their wing muscles.

The furry and wax-like coatings of certain tundra plants are also adaptations that enable the plant to resist cold and wind. Fine hair or fuzz slows the wind and thus reduces the "wind chill" or loss of heat. The fine dense hair around the flowers of the wooly lousewort not only reduce wind chill, but also trap heat from sunlight like the glass of a greenhouse. The flowers are thus surrounded by relatively warm air, sometimes 34° F (20°C) warmer than the environment. This is quite important because the process of cell division, necessary for the formation of seeds, can not occur at cold temperatures. The waxy coating of many plants reduces water loss and evaporative cooling by the wind. Many tundra plants retain, rather than shed, their dead leaves each year. The dead leaves serve no apparent purpose except they insulate the fragile new buds from the wind and cold. Grass tussocks provide a good example of this.



Wooly lousewort, a tundra plant, is covered with hairs that help block the wind and trap warm air around its leaves and flowers.

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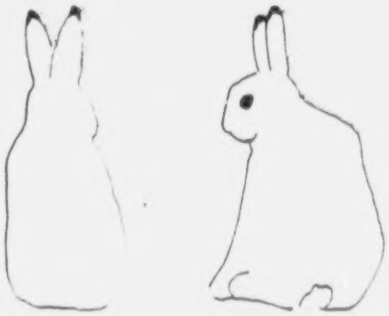
SIZE, COLOR, LONG EARS, AND HEAT...................SCIENCE / MATH ....Indoors/Outdoors

OBJECTIVES: Students will discover why size, color, and length of appendages make a difference to arctic animals.
SKILLS: measuring, comparing, inferring, predicting, concluding
MATERIALS: For Experiment 1: a thermometer, large and small pails, warm water, access to outdoors or a refrigerator; For Experiment 2: 2 thermometers, 2 tin cans, 1 painted white, 1 painted black, warm water, sunlight or incandescent light bulb; For Experiment 3: 2 thermometers, 2 pairs of thin plastic or rubber gloves, rubber bands, 1 measuring cup, pail, warm water; Also: Selected Adaptation Cards
PROCEDURE:
Three separate experiments are described on this and the following pages. These are written so that small groups of students could work on the experiments on their own. However, with primary students, it is preferable to have the class discuss the questions and do the experiments together.

NOTE: You may want to check the length of time required to show each of the differences, as this will vary depending on the size of the containers you use, the starting temperature of the water, and the temperature of the sites where you place the various objects. Fifteen minutes is likely a minimum estimate.



EXPERIMENT 1: SIZE AND HEAT

1. Which do you think loses heat (or gets cold) faster, a large object or a small one? (Write down your answer.)

2. You can find out by running a test. Fill a large and a small pail with warm water. Measure the temperature of the water in each pail and write it down.

Starting Water Temperature in Large Pail_____
Starting Water Temperature in Small Pail_____

3. Place both pails outside or in a cold place for 15 minutes. Then take another measurement of the water temperature in each pail. Write these measurements down.

Ending Water Temperature in Large Pail_____
Ending Water Temperature in Small Pail_____

4. Subtract the ending temperature from the starting temperature and record your answers.

Starting Temperature minus Ending Temperature in Large Pail = _______

Starting Temperature minus Ending Temperature in Small Pail = _______

Which one cooled down more? Which loses heat faster, a large object or a small one? Did you predict the correct answer?

5. Based on what you found out about the relationship between cooling and the size of objects, do you think that animals that live in tundra environments should be larger or smaller than animals living in warm environments?

EXPERIMENT 2. LONG EARS AND HEAT

1. Which do you think keeps your hands warmer--gloves (with separate places for each finger) or mittens? (Write down your answer.)_______

2. You can discover which is warmer by running a test. First take a pair of rubber gloves. Use a rubber band to close off the four finger compartments in one of the gloves. Be sure the rubber band is tight. This will be called the No Finger Glove. The other glove will be called the Normal glove.

Get a pail of water and measure the temperature of the water. Write this measurement down.

Starting Temperature of the Water_______.

Now measure 1 cup of water and pour this into the NoFinger glove. Close the top of the glove with another rubberband. Be sure to close it tightly so it won't leak.

Measure another cup of water and pour this into the Normal glove (which still has finger compartments). Close the top of this glove with another rubberband. Again, be sure to close it tightly so it won't leak.

Place both gloves outside or in a cold place, near each other, but not touching. Wait 15 minutes, then bring them both inside. Pour the water in the No Fingers Glove into 1 cup and the water in the Normal Glove into another cup. Measure the temperature of the water in both cups. Record your answer:

Ending Temperature of water from No Finger Glove________

Ending Temperature of water from Normal Glove_______

In which one did the water get colder?
How would you explain this difference?

Next time its cold and you go outside, will you wear mittens or gloves to keep your hands warm?

Now think about animals that live in the arctic. The blood in their bodies is like the water in the gloves. Their toes, ears, and tail are like the fingers in a glove. Considering what you know about gloves and water temperature, which animal do you think would stay warmer in the arctic--one with long ears, toes, and tail, or one with short ears, toes, and tail?

Compare the ears of the Arctic Fox to those of the Kit Fox, and the ears of the Tundra Hare to those of the Desert Jackrabbit (shown on the Adaptation Cards). Can you give a possible reason for the differences you observe?

EXPERIMENT 3. COLOR AND HEAT

1. Which do you think would be a warmer coat--a black one or a white one?

2. You can find out the answer by doing an experiment. First you'll need 2 tin cans--one painted black and one painted white. Get a pail of warm water and measure the temperature of the water. Record this:

Starting Temperaure of Water: ________ Black Can

________ White Can

Now fill each of the cans with water. Place them outside in the sunlight, or under a bright light.

3. Wait about 15 minutes. Then, retrieve the 2 cans. Measure and write down the temperature of the water in each can:

Ending Water Temperature in Black Can________
Ending Water Temperature in White Can________

4. Based on this experiment, which color of coat would be warmer?______________________________

5. Based on your experiment, do you think animals that live in the cold arctic tundra should be black or white? _______
Why?______________________________
Make a list of tundra animals and their colors. How many of them are the color you predicted? How many are a color you didn't predict? Why might this be?__________

6. You might want to try another experiment to better understand the relationship between color and staying warm. Take the 2 cans again, fill them with warm water, then place them outside in the shade or in a dark place. Wait 15 minutes then measure the water temperature in each can again.

Ending Water Temperature in Black Can _______
Ending Water Tempearture in White Can_______

Did you get the same results as in the first experiment? Why or why not?______________________________

7. Can you now explain the color of many tundra animals? Why might many animals have different winter and summer colors?______________________________

8. Next time you go outside on a sunny day, which color of coat will you choose to stay warm? Next time you go outside at night, what color would you choose to keep warm?

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HUMAN ADAPTABILITY....................................SOCIAL STUDIES / SCIENCE

....Indoors

OBJECTIVES: Students will recognize that humans cope with their environments by using tools and learning.
SKILLS: reading, comparing, inferring.
MATERIALS: Blackboard, chalk, reference materials about people living in the arctic.
PROCEDURE:
1. REVIEW THE PROBLEMS FACING LIVING THINGS IN A TUNDRA ENVIRONMENT. Write on the blackboard "Problems of Living in the Tundra" as the heading of a column. Ask students to list some of the problems faced by organisms that live in tundra environments. With prompting, students should be able to list Cold Temperatures, Long Winters with Little Food, Short Growing Seasons, and Wind. List these on the board.

2. REVIEW PLANT AND ANIMAL ADAPTATIONS FOR TUNDRA LIFE. Write "Animal and Plant Adaptations to the Tundra" as the heading of a second column to the right of the first. Ask students how tundra organisms are able to survive these problems. Students should be able to describe some of the traits, or adaptations, of tundra organisms which allow them to tolerate the "problems." List the adaptations named under the second column heading next to the related "problem." (If students can not describe some of the adaptations of tundra organisms, hand out the adaptation cards that show tundra animals and plants. Ask students to read the cards and then name some of the traits that help organisms survive in the tundra.)

3. DISCUSS WAYS HUMANS COPE WITH LIFE IN THE TUNDRA: Write a third column heading on the blackboard: "Human Methods of Surviving in Tundra." Then ask students to list specific ways that humans deal with the same problems that other tundra organisms must face. (E.g., Problem: Cold--people wear coats, build warm houses, use fire, or migrate (by going to Hawaii or the Lower 48); Long Winters with Little Food--people store food from summer; bring food in from elsewhere, or go elsewhere to find food.)
OPTIONAL: Have students use reference materials (books, encyclopedias, etc.) to learn how humans survive in tundra environments around the world.
4. DISCUSS THE SIMILARITIES AND DIFFERENCES BETWEEN ANIMAL AND PLANT ADAPTATIONS, AND HUMAN METHODS OF SURVIVAL IN TUNDRA. Students are likely to see the similarities between the ways other living things are adapted to the tundra and the ways humans survive. However, it is also important that students recognize the differences.

Animal and plant adaptations are genetically determined--meaning that tundra organisms do not choose, or decide, to grow thick fur for winter, or migrate, or grow large, or turn white. Adaptations are genetic traits, just like the colors of student eyes and hair, or student height, foot size, etc.

In contrast, most of the human methods of surviving in tundra environments are matters of choice. A person decides whether to "migrate" or stay through winter; whether to wear warm coats or stay in a warm house; whether to gather and store extra food during summer, have extra food shipped in from elsewhere, or go elsewhere to find food.

Encourage students to discover and understand this contrast by asking them whether or not an arctic fox (for example) could decide to migrate south. Could a plover decide to store food, grow a thick coat of warm feathers, and stay through the winter instead of migrating? If you planted the seed of a cushion plant from the tundra in a place with no wind, would it grow tall? Could a caribou "adapt" to a hot, dry desert environment? (If students have difficulty grasping that these adaptations are not decisions made by the plants and animals, ask them whether they could decide to grow a fur coat, or turn white in winter. They will soon realize that an animal or plant could not do so either.)

What about the methods people use to survive? Could an Inuit Native move to the desert and survive? Or, could someone from the tropics survive in the arctic? How? (By learning human methods of dealing with that environment.) Discuss the implications of this difference. Could tundra plants and animals survive if the tundra environment was somehow changed?

NOTE: Races of humans that have lived in a particular environment for thousands of years also have genetic adaptations to their environments. For example, the relatively small stature and build of arctic people are adaptations for surviving in cold and with less food during the long winters and food shortages typical of the north. Twilight vision (and associated color blindness) is more common in races of arctic people than in races of people who live at lower latitudes. This represents an adaptation for use of the long twilight periods that occur at high latitudes. Races of people native to tropical climates have physiological adaptations for resisting some of the diseases of their environment.

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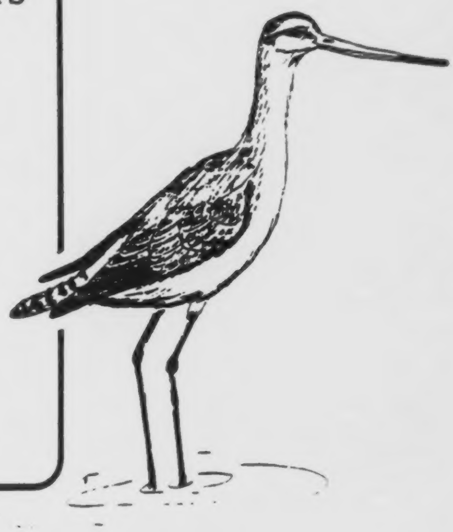
TUNDRA ADAPTATIONS.......LANGUAGE ARTS

OBJECTIVES: Students will be able to identify some of the adaptations of tundra animals and plants.

SKILLS: reading comprehension

MATERIALS: Adaptation Close-ups (page 54 to 57)

PROCEDURE:
Have students read the Adaptation Close-ups. You may have each student read all of them, or assign separate ones to individuals who then report what they read to the class. Have students complete the Reading Comprehension Worksheet for each of the close-ups they read. This can be used to evaluate reading comprehension..



MICROHABITATS..
OUTDOORS...SCIENCE

OBJECTIVES: Students will recognize that environmental conditions vary considerably even within a small area, and that living things seek out sites with the most tolerable conditions.
SKILLS: observing, comparing, inferring
MATERIALS: clear plastic bags (non-leaking), felt-tip pens (that draw on plastic), rubber bands, gelatin, boiling water, a measuring spoon (1 Tablespoon); Optional: thermometers, anemometers
PROCEDURE:
1. PREPARATION: Dissolve 1 package gelatin in 1 1/2 cup boiling water. Set aside to cool but do not allow to set up.
2. STUDENTS PREPARE GELATIN ANIMALS: Give each student a plastic bag. Ask them to draw a picture on the plastic bag of a small tundra animal. Then, have each student put 2 Tablespoons of gelatin in their bag and seal the bag shut with a rubberband.
3. STUDENTS FIND A PLACE FOR THEIR ANIMAL TO LIVE. Ask each student to put their animal in a spot where they think it could live. Wait 10 minutes, then have students check on their animals. Did any of them "freeze" (gel)? What kinds of places were these animals in? Explain that if an animal freezes, it can't live. So, tundra animals try to find places where they won't get as cold. Allow students to move their animals to new places if they want. Then recheck the animals every 3-5 minutes. Which animals stayed unfrozen the longest? What was different about the sites these animals were in? Were they warmer? Better insulated? More sheltered from the wind?
4. STUDENTS COMPARE THE SITES. Have students measure the temperature and wind speed at the sites where the animals froze quickly and compare these to the sites where the animals froze more slowly. Do they find any differences? If the temperatures and wind speeds are the same, what about the insulation at the two sites? Would an animal stay warmer in a nest of grasses or in the same spot without a nest? In a nest of eider down? Why? (The nest would be warmer because it provides insulation, thus trapping heat released by the animal. Thus the animal wouldn't lose heat as quickly and could stay warm longer.)
5. STUDENTS LOOK FOR EVIDENCE OF ANIMAL USE OF MICROHABITATS: Have students explore the area and look for animals and plants that make use of sheltered spots and insulation. Can they figure out some good places to look for insects and signs of other animals based on what they now know about microhabitats?

CREDIT: This activity is adapted from Outdoor Biological Instructional Strategies, Lawrence Hall of Science, University of California, Berkeley, California; see the reference list for information on obtaining these excellant educational materials.

FREEZE-DRIED PLANTS...Science, Math

OBJECTIVES: Students will recognize that organisms that live in cold environments have adaptations to withstand cold.
SKILLS: observing, comparing, inferring
MATERIALS: a stem with fresh leaves of a cranberry plant (or other tundra plant) and a stem with fresh leaves of a houseplant such as a philodendron or coleus, freezer, fan. Optional: thermometer, several jars, water, vinegar, sugar, antifreeze, a blackfish
PROCEDURE:

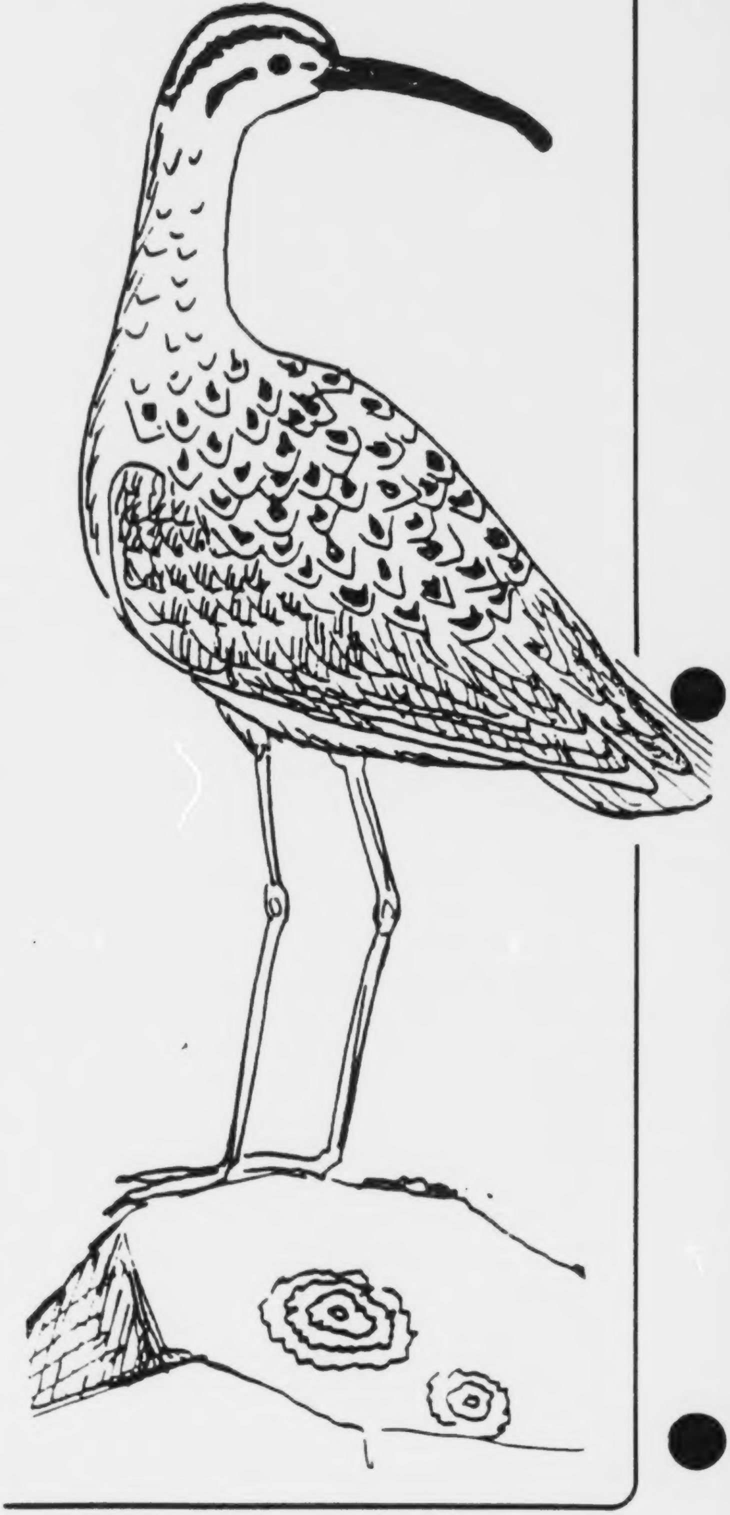
1. STUDENTS COMPARE THE LEAVES. Do not tell students what plants the leaves are from. Ask students to look carefully at the two types of leaves and write down any differences they see. Ask them to draw illustrations of each kind of leaf.
2. EXPOSE LEAVES TO COLD AND WIND. Tie one or more of each kind of leaf in front of a fan; turn the fan on high. Place one or more of each kind of leaf in a freezer. Have students observe the changes in the two kinds of leaves at 10 minute intervals and record these with notes and illustrations.
3. DISCUSS THE RESULTS: Which kind of leaf was changed most by the cold and air movement (wind)? Were these changes good? Would the leaf still live after the changes occurred? (Place both leaves in water to find out if there is any question.) Can students infer from the results which plant would survive best in a tundra environment? Why wouldn't the houseplant survive there? Why can the other plant tolerate the cold and wind more? (It has adaptations to resist cold and wind, including small leaves with a thick, waxy coating, a habit of growing flat along the ground (thus avoiding wind), and it produces antifreezes that prevent the fluid in its cells from freezing.
4. DEMONSTRATE THE EFFECTS OF FREEZING AND ANTIFREEZE: Fill and seal a plastic container with water. Explain to students that it represents a cell. Freeze it and discuss the effects. (The expansion of the water as it freezes should break the container or pop the top.) Demonstrate the effects of antifreeze by freezing various solutions of water (mix separate solutions of plain water, and water with varying amounts of dissolved sugar, alcohol, or antifreeze. Be sure to label the various solutions.) Try to freeze the solutions. Measure and record the temperatures of each solution every 10 minutes until it freezes. Which mixture reached the lowest temperature before freezing? Does the amount of material in solution affect the freezing temperature?

Demonstrate the tolerance of a blackfish to freezing by placing a live one in a freezer for 15 minutes, then returning it to the water. [This remarkable fish can survive this treatment because it has antifreezes in its body, and it is able to breathe air through its esophagus (in addition to getting oxygen from water through its gills). Some have survived being frozen for 45 minutes--however, parts of the fish must remain unfrozen for it to survive.]

ADAPTATION CLOSE-UP 1. Read the article below, then color the picture.

The Whimbrel

The whimbrel is a bird that lives in alpine and lowland tundra around the world. It has a long curved bill which it uses to probe for insects in moss and mud. Whimbrels stand about 1 1/2 feet tall. They have certain traits, or adaptations, that allow them to live in tundra environments. Whimbrels lay 4 eggs in a small scrape on the ground. Their brown feathers and their spotted brown eggs match the colors of tundra lichens and plants. This helps keep the nest hidden from predators, like arctic fox and parasitic jaeger. While nesting, one of the parent whimbrels keeps watch. It warns its mate if any predators come near. Whimbrel chicks are covered with down when they hatch. They can run around within 10-15 minutes after hatching. They then follow their parents and soon learn to find and catch insects. Compared to the chicks of birds that live in other environments, whimbrel chicks grow quickly. Within 6 weeks they are able to fly. This is important because the summer season in the tundra is very short. Whimbrels have long wings and hollow bones. These traits enable them to fly long distances. Each fall whimbrels leave the tundra and fly 4000 to 7000 miles south. They spend the winter along the Pacific coasts of southern California, Mexico, and Central and South America. They are able to find many invertebrates to eat on their wintering rounds. Their habit of migrating south allows them to avoid the long, cold winter of tundra, and to find enough food to survive. In spring, they return north to nest on the tundra again.



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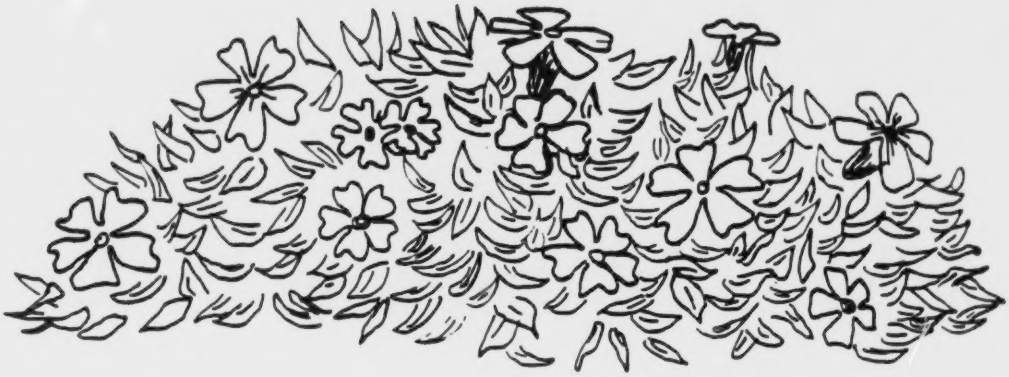
Read the article below, then color the picture.



Moss Campion

Moss campion is a small plant that grows in alpine and lowland tundra. It has tiny green leaves and tiny purple flowers. It grows only 2 inches tall. Some people call it a "cushion plant." Don't let its small size fool you. A 2 inch tall plant may be 50 years old. Like many tundra plants, moss campion lives for many years. The plant lies dormant, or sleeping, during each long winter. Most of the plant's leaves die in the fall, but underground, sheltered from the wind and some of the worst cold, the roots survive. The energy and minerals stored in this plant's large roots allow it start growing when summer returns. The summer in the tundra is so short that the plant must form flower buds one year, then bloom and make seeds the next.

Moss campion has many traits, or adaptations, that allow it to survive the cold and wind of the tundra. Its small size helps because the wind is not as strong near the ground as it is a few inches above the surface. Also, the ground absorbs heat from the sun, so the air is often warmer near the ground, too. The cushion shape of the plant also helps trap heat. The leaves and flowers near the center of the cushion are kept warm and sheltered from the wind by the surrounding leaves. Sometimes the temperature in the center of the cushion is 20 degrees warmer than the surroundings. Sunlight warms dark-colored surfaces faster than light ones. That may be one reason that moss campion has purple flowers instead of white or yellow ones.

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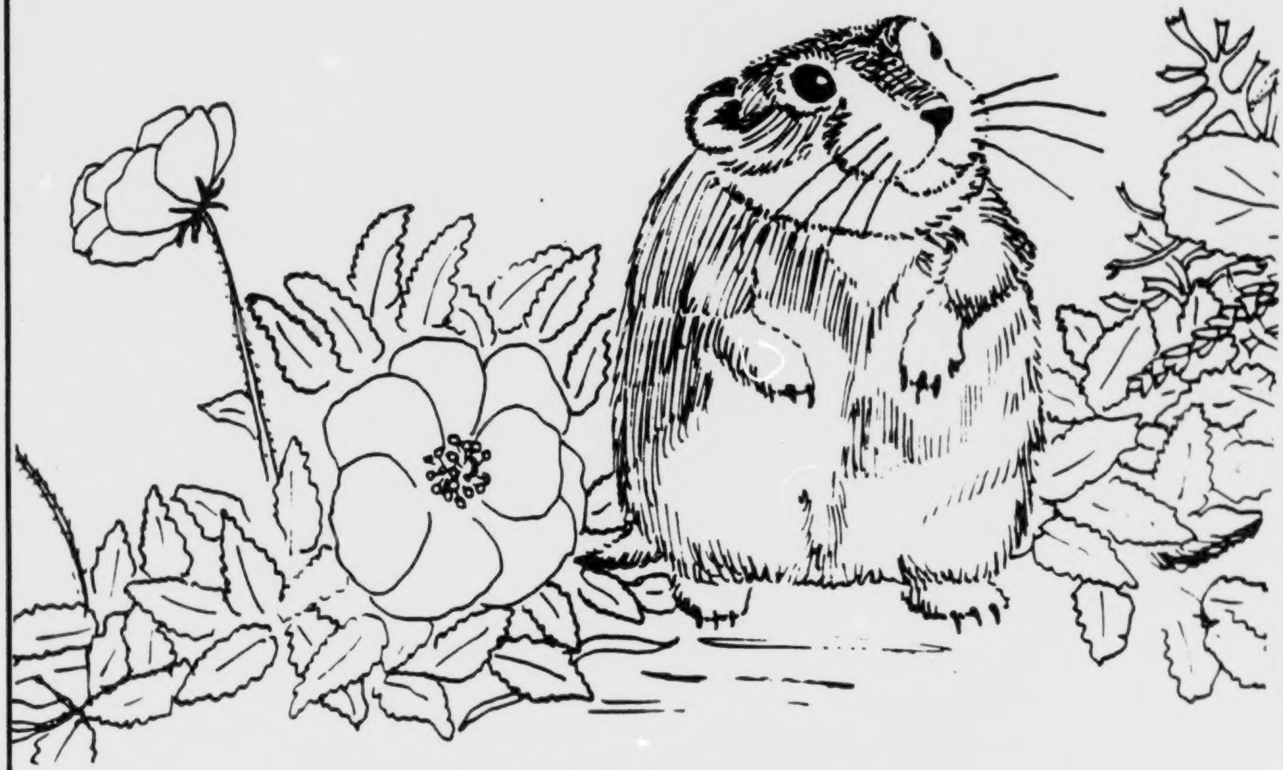
ADAPTATION CLOSE-UP 2. Read the article below, then color the picture.



The Collared Lemming

The collared lemming is a mammal that lives in the tundra of northern Alaska and Canada. Keeping warm is one of its biggest problems. This small, mouse-like animal has many traits that help it survive the long, dark, and cold winters. Most mice have large ears and long tails. But a long tail and large ears can easily freeze in severe cold and wind. That is why lemmings have short ears and a short tail. Most mice have short, thin hair. But lemmings have long, thick fur to help them stay warm.

Lemmings avoid some of the cold of winter by living under the deepest snow patches. The temperature under the snow is often warmer than the temperature above the snow. Collared lemmings grow special shovel-like claws in fall. These claws help the lemmings dig tunnels under and through the snow. Lemmings also gather mosses and grasses to build nests under the snow. The mosses and grasses insulate their nests and help the lemmings keep warm.

Collared lemmings are the only mice that change color. They turn white in winter. The white color of their long fur cuts down on the rate that they lose heat to their codl surroundings. It also helps camouflage (or hide) them from arctic foxes and snowy owls. These predators also turn white in winter, which may help them stay warm and sneak up on their prey. The traits that help lemmings survive in the tundra environment are called "adaptations."

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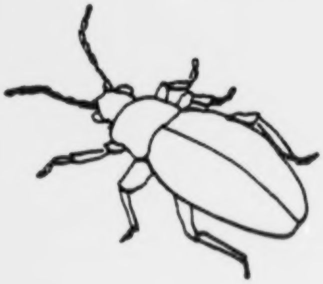
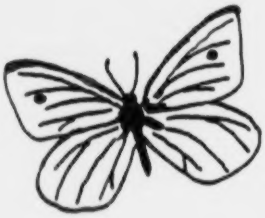
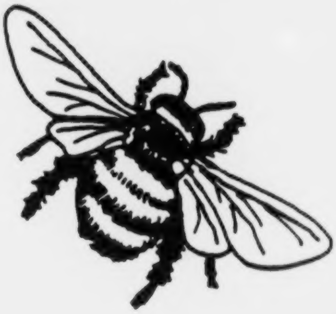
ADAPTATION CLOSE-UP 4.

Read the article below, then color the picture.







Tundra Insects

The tundra is a severe environment for an insect to live because most insects are cold-blooded. That means that their blood temperature is strongly affected by the temperature of their surroundings. When an insect is cold, it can't move. In tundra environments, the air temperature is usually very cold. However, many insects live in tundra, despite the cold. Tundra insects have special traits, or adaptations, that allow them survive in the cold.

Many tundra insects are small. This helps them stay warm because they can find places that are protected from cold winds. Some can also find warm places to live. The soil is usually warmer than the air, so many insects live in the soil. Some insects live in the center of certain flowers. Some flowers, like dryas, have large white petals and turn to face the sun. Like small mirrors, the petals reflect the sunlight and heat toward their centers. This keeps the flower center, and the insects that live there, much warmer than their surroundings.

Sunlight can quickly warm dark-colored objects. That is why many tundra insects have dark-colored bodies. Some tundra butterflies rest with their dark wings turned to catch the warm sunlight. If it weren't for the warm sunlight, they wouldn't be able to move their muscles and fly.

Have you noticed that your body gets warm when you run a long ways? This happens because your muscles release heat when they move. Tundra bumblebees have special muscles which they can move just to make heat. This heat would quickly escape into the air if not for the velvet-like hair, or fur, that covers a bumblebee's body. This fur traps the heat made by the muscles and keeps the bumblebee warm. That is why some bumblebees can fly even when the air temperature is below freezing.

Winter is the most difficult time for tundra insects. If they freeze or dry out, they will die. Insect eggs do not dry out or freeze as easily as adult insects. That is why most insects only live for 1 year. Adults lay eggs in fall, then die. Only the eggs survive the winter. Some adult insects, such as certain ground beetles, can survive a tundra winter though. These insects make antifreezes. These special chemicals keep the insect's blood and cells from freezing.

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Reading Comprehension Worksheet

Lemming

1. A lemming is a   bird   fish   mammal
2. It lives in the   forest   tundra   desert
3. It has traits that help it survive   without water   cold temperatures
4. These traits are called   characters   adaptations
5. Which of the following traits help lemmings survive cold?
    short hair   long tail   short tail   long fur   small ears
    shovel-like claws   small eyes   big feet   white winter fur
6. The main predators of lemmings are   black   white   brown

---

Moss Campion

1. Moss campion is a   fish   plant   mammal   bird
2. It has traits that help it survive
    short winters   without water   cold temperatures and wind
3. These traits are called   cushions   adaptations
4. Which of the following traits help moss campion survive cold?
    large leaves   purple flowers   cushion shape   small size
5. Could a 2-inch tall plant be 50 years old?   yes   no
6. How many summers does moss campion take to produce flowers and seeds?
    1/2   1   2   3

Whimbrel

1. A whimbrel is a   plant   mammal   bird   fish
2. Whimbrels nest   in the north   in the south
3. It has traits that help it   stay cool   fly   avoid predators
4. These traits are called   camouflage   predators   adaptations
5. Which of the following are traits that help whimbrels survive in tundra?
    shovel-like claws   migration   eggs that match the lichens and plants
    chicks that grow quickly   webbed feet
6. Whimbrels spend the winter in
    the tundra   on the plains   along the coasts

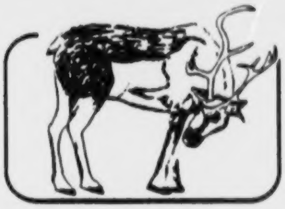
Insects

1. How many insects live in tundra environments?   few   none   many
2. Most insects survive the winter as   adults   larvae   eggs
3. Insects are cold-blooded. That means their blood is
    warm   cold   affected by the surroundings
4. Traits that help an insect survive in a particular environment are called
    antifreeze   adaptations
5. Which of the follwing are traits that help some insects survive the cold?
    fur   dark-colored bodies   small size   antifreeze   big feet
6. Can insects make heat by moving their muscles   yes   no

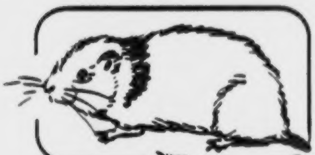
Worksheet 3.
Tundra Adaptations

Name____

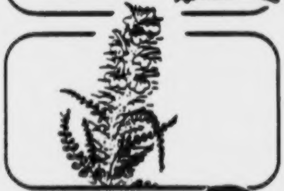
Match each animal to that trait which helps it survive in a tundra environment.



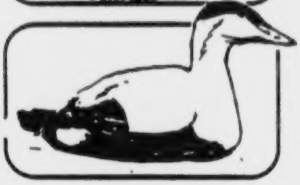
Caribou
1.______



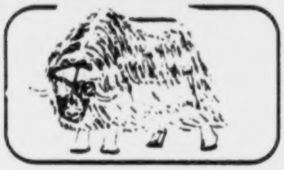
Lemming
2.______



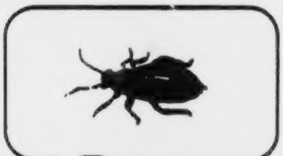
Wooly Lousewort
3.______



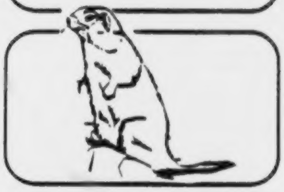
Eider
4.______



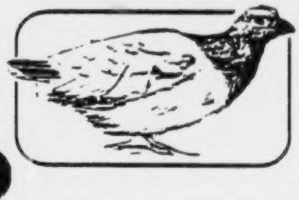
Muskoxen
5.______



Ground Beetle
6.______



Arctic Ground Squirrel
7.______



Willow Ptarmigan
8.______

a. shovel-like claws that help it dig through the snow

b. flowers that reflect light and heat toward their centers, and wax-coated leaves that resist freezing and drying

c. large ears and a long tail that lose excess heat

d. leaves, stems, and flower stalks covered with hairs that break the wind and trap heat from sunlight

i. makes special chemicals, called antifreezes, which help prevent its cells from freezing.

n. unusually large feet for walking across and pawing through snow and a coat of hollow hairs

o. a thick layer of soft down feathers that trap air and heat next to their body

p. two layers of warm fur, including a thick, downy underlayer and guard, or outer, hairs that are 12 inches long

r. wings that radiate heat to the surroundings

s. the ability to reduce its heart rate, breathing, and body temperature so that it can live for several months without eating

t. grows feather snowshoes and turns white in winter

If you matched each organism to the correct trait, the letters of your answers will help you decode this secret science word:

2-3-2-5-8-2-8-6-4-1-7

Lesson 4.

Vocabulary:

commensalism, cycle, decomposition, detritus, food chain, food web, interdependence, mutualism, parasitism, peat, population, symbioses

Objectives:

Students will be able to describe some of the inter-relationships between the non-living environment and living things of tundra ecosystems, including food webs and symbioses.

Teacher Background:

Tundra ecosystems, like all others, are made up of all the non-living and living things present and the interactions among these. Tundra ecosystems are sometimes considered simple ecosystems because they are made up of relatively few species of plants, animals, and other living things (as compared to other kinds of ecosystems). Nevertheless, the non-living environment and living things in tundra ecosystems are tied together in complex ways. A summary of important points about the inter-connections within tundra ecosystems is provided below. More details are provided on the following pages.

1. FOOD CHAINS AND WEBS: Energy and minerals are exchanged between the non-living surroundings and living things via food chains and webs. However, the flow of these is considerably less than in other ecosystems because of the short growing season and cold temperatures.

Tundra producers make only one tenth to one third the food made by producers in forest ecosystems each year, and decomposition occurs very slowly. Tundra ecosystems have two important types of food chains, herbivore-based and detritivore-based. Only a small proportion of the food produced each year is consumed by herbivores, which are in turn eaten by carnivores. Instead, most of the material produced dies. Due to slow rates of decomposition, partially decayed material, called detritus, accumulates. The detritus is consumed by certain detritivores, which, in turn, are food for many tundra carnivores. Most detritivores feed on dead material from recently dead plants and animals, but some detritivore-based food chains exchange energy and minerals from peat--the detritus of producers that lived 1,000-12,000 years ago.

2. POPULATION CYCLES: Many populations of tundra animals fluctuate between high and low numbers. Some populations appear to fluctuate in a regular pattern, or cycle. Scientists do not yet understand all the reasons that such fluctuations occur, but plant-herbivore interactions, predator-prey interactions, behavior, genetics, and nutrient (mineral) recycling to the soil may be involved.

3. SYMBIOTIC ASSOCIATIONS: Many living things in tundra ecosystems interact with and depend upon other species in associations called symbioses. Three kinds of symbioses are recognized: mutualism, commensalism, and parasitism. Lichens, pollination, and mycorrhizal associations are examples of mutualistic symbioses--associations from which both interacting species benefit. The dependence of scavenging foxes and ravens on predatory wolves and bears, and the association of nesting birds with species that give predator-alarm calls, are examples of commensalism--symbioses from which one species benefits and the other is unaffected. In parasitic symbioses, one species, the parasite, benefits, while the other, the host, is harmed. The relationship between warbleflies and caribou is an example of parastitism.

4. OTHER CONNECTIONS BETWEEN NON-LIVING AND LIVING SYSTEMS: Some connections between the non-living environment and living things are more easily observed in tundra ecosystems than in perhaps any others. Changes of a few inches in elevation, a few days worth of snow cover, or a few degrees in aspect cause striking differences in the species of plants and other organisms that can survive. In addition, all the variation in environment and living things can occur within a few square meters of tundra. Similarly, the influence of living things on the non-living environment is striking and easily observed. The effects of vegetation on soil temperatures is dramatically revealed by the melting of permafrost and drastic changes in soil that occur whenever plant cover is removed or disturbed. The importance of nutrient recycling is clearly revealed by the lush growth that occurs around owl and jaeger perches, around ground squirrel and arctic fox dens, and around bones and carcasses of dead animals.

TUNDRA FOOD CHAINS AND WEBS:

The non-living things in tundra ecosystems include air, water, soil, rocks, and energy. Energy and minerals (defined as elements and common compounds) make up both non-living and living things. As in all ecosystems, the energy and minerals from the non-living environment move among living things via food chains and webs, then return to the non-living environment. Simply stated, a FOOD CHAIN is the pathway of energy and minerals from the non-living surroundings through producers and consumers and back. A FOOD WEB is made up of all the interconnecting food chains in an ecosystem.

PRODUCERS are those organisms that convert (through photosynthesis) energy from sunlight and minerals from the air, water, and soil into food for other living things. Plants, algae, and lichens are all important producers in tundra ecosystems.

Tundra producers can only function for a few months each year due to lack of light (from darkness and/or snow cover), low light intensity, cold temperatures, and lack of moisture. Thus, tundra producers are like a bottleneck limiting the flow of energy and minerals through the ecosystem. Scientists measure the flow of energy and minerals by determining the weight of carbon that is changed into living material (or fixed) by producers each year. The dry weight of all new growth--leaves, roots, flowers, cells, etc. is used to estimate carbon fixation. On average, all tundra producers together fix only 200 gms of dry weight per year per square meter (range of 100-1000 gm/m2/yr). In comparison, producers in forests fix an average 2000 gms of dry weight per square meter per year (range 1060-3460 gm/m2/yr). In other words, tundra producers make only 1/10-1/3 as much food each year as producers in forest ecosystems. This may be part of the reason that few species of herbivores occur in tundra ecosystems, and why large herbivores (such as caribou and muskoxen) travel over large areas of tundra to find food.

CONSUMERS, those organisms that cannot make their own food, form all the other links in food chains. Consumers are divided into several sub-groups, or trophic levels, based upon the foods they eat; these categories are herbivores, carnivores, and detritivores. Omnivores are consumers that function at 2 or more trophic levels.

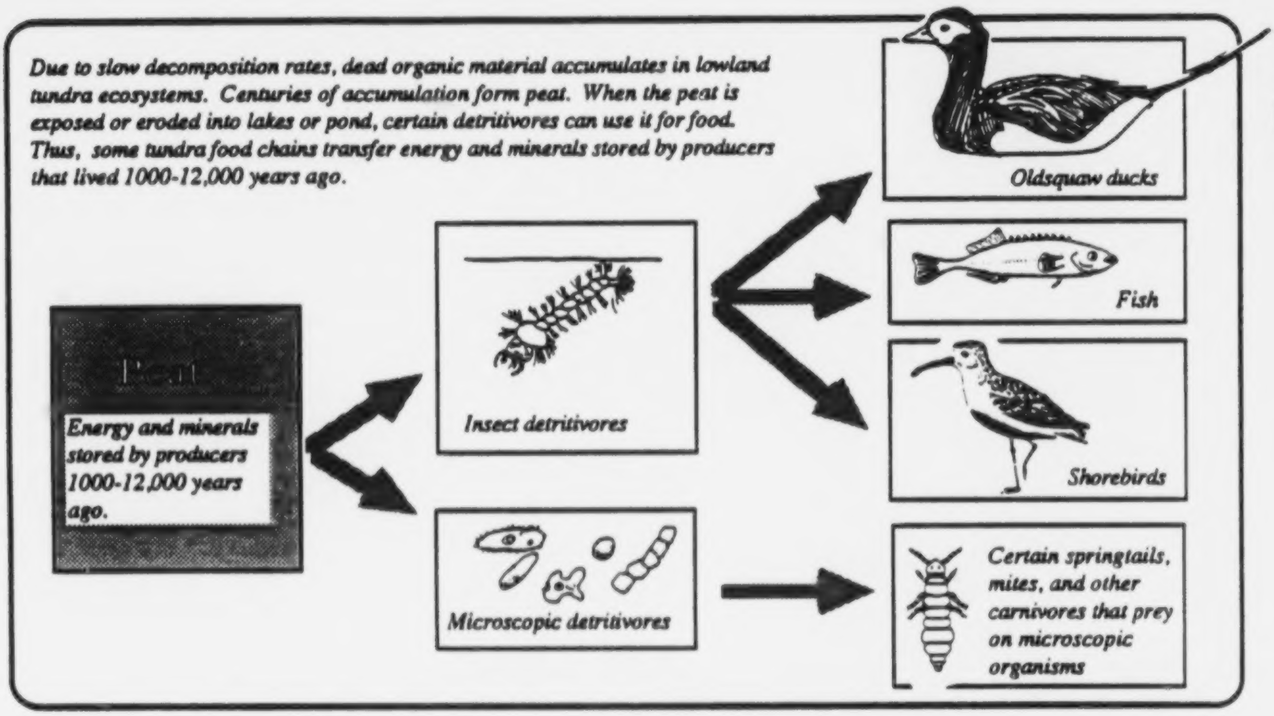
HERBIVORES are organisms that eat producers. Lemmings, caribou, and geese are the most noticeable and important herbivores in lowland tundra ecosystems. Voles, pika, marmots, Dall sheep, and mountain goats are the most obvious and important alpine tundra herbivores. Invertebrate animals, particularly insects, are also important herbivores in some tundra environments. Bumblebees, moths, butterflies, aphids, and sawflies are examples of invertebrate herbivores.

Wolves, wolverines, arctic foxes, weasels, jaegers, gyrfalcons, golden eagles, and snowy and short-eared owls are conspicuous and important CARNIVORES of tundra ecosystems. These animals prey on the abundant vertebrate herbivores of tundra. Many kinds of small, insect-eating shorebirds are important carnivores in tundra ecosystems, despite the scarcity of insect herbivores (the reasons for this are discussed below). Relatively few insect-eating invertebrates occur in tundra ecosystems, but some predatory craneflies, spiders, and ground and rove beetles occur.

Most tundra consumers eat a variety of foods depending on what they can find, because food is often scarce. Typical herbivores such as arctic ground squirrels sometimes eat bird eggs, and caribou, which eat mainly plants and lichens, have been observed eating bird eggs and even lemmings. However, some tundra animals function at all 3 trophic levels (herbivore, carnivore, and detritivore.) They are called OMNIVORES. A brown bear is probably the best example of an omnivore; ground squirrels, carrion, and plant roots and berries, and (sometimes) caribou calves are all important parts of their diet in tundra ecosystems.

DETRITIVORES, consumers of dead organisms, are often overlooked, but are extremely important in all ecosystems. Detritivores perform the opposite task of producers by returning minerals and energy locked in dead (formerly living) things to the non-living surroundings. Without detritivores, producers would soon run out of the minerals they need to make food. Important tundra detritivores include: enchytraeid worms, springtails, mites, the larvae of many kinds of flies, nematodes, certain fungi, and microscopic organisms, including bacteria and protozoans.

continued on next page



Due to slow decomposition rates, dead organic material accumulates in lowland tundra ecosystems. Centuries of accumulation form peat. When the peat is exposed or eroded into lakes or pond, certain detritivores can use it for food. Thus, some tundra food chains transfer energy and minerals stored by producers that lived 1000-12,000 years ago.

Peat
Energy and minerals stored by producers 1000-12,000 years ago.
Insect detritivores
Microscopic detritivores
Oldsquaw ducks
Fish
Shorebirds
Certain springtails, mites, and other carnivores that prey on microscopic organisms

Despite the abundance and variety of detritivores in tundra ecosystems, they represent a second bottleneck in the flow of energy and minerals. Most detritivores can only function in the top few inches of tundra soil (the top 2 in (5 cm) in the arctic) and only during a few short months each year because of the cold temperatures and (on some sites) the wet, acidic soils. The weight of all the dead material broken down by tundra detritivores is slightly less than the weight of new material made by producers each year. As a result, dead, partially decayed material, called DETRITUS, slowly accumulates in tundra ecosystems. In alpine tundra, wind and water erosion carry away much of the excess. But in flat areas of lowland tundra, particularly in the arctic, centuries of accumulation have created thick layers of detritus, called peat. A lot of energy and minerals are locked up in this peat layer.

At each link in every food chain, some energy is returned to the environment as heat and is lost to the ecosystem. It can not be reused. Because energy is not recycled, all ecosystems must have a constant resupply of energy from the sun, and this must be continually converted into food by producers. In contrast, minerals are recycled. Those that become part of a producer or consumer are passed along through food chains, until they are returned to the non-living surroundings where they are available for re-use by producers. Because of slow decomposition rates in tundra ecosystems, much of the nitrogen, phosphorus, and calcium that could be reused by producers is insteadtied up in the accumulated detritus and is not available. As a result, the growth and production of many tundra producers is limited by lack of these minerals.

DETRITUS FOOD CHAINS–Despite the low productivity of living producers in tundra ecosystems, a surprising variety of consumers, particularly carnivores, flourish. This occurs because many tundra food chains are based not on living producers, but instead on dead organic material and, in the case of some food chains in tundra ponds and lakes, on peat. Detritivores break down waste materials and return energy and minerals to the non-living surroundings, but some of the food (energy and minerals) they consume is incorporated into their bodies. Many carnivores, including certain insects, ducks, shorebirds, and fish get the energy and minerals they need by feeding on detritivores. The energy and minerals in accumulated organic material thus forms the base of some arctic tundra food chains. Essentially, the consumers in detritivore-based food chains live off energy and minerals stored by tundra producers in past years. The consumers in peat-based food chains are actually supported by producers that lived 1,000 to 12,000 years ago!

POPULATION CYCLES:

Populations of many tundra animals, including lemmings, voles, redpolls, ptarmigan, and perhaps caribou, repeatedly fluctuate between high and very low levels. Population changes that occur repeatedly, and on a regular schedule are called "population cycles." This phenomenon is fascinating and puzzling to scientists. The population changes of brown lemmings in arctic tundra have been examined more closely than those of any other animal.

Brown lemmings occur at low densities [0.1-0.2 lemmings / acre (0.4 ha)] in many years, but in some summers, they become much more abundant [40-100 lemmings / acre (0.4 ha)]. The change from low numbers to high occurs in just 1-2 years, and the crash from high to low in just one summer. Near Barrow, the peaks in lemming numbers seem to occur every 3-6 years. In other areas, there is no recognizable pattern.

Scientists first thought that lemming populations cycled as a result of predators. During years when lemming numbers are high, resident predators such as weasels and foxes raise more young, and thus take more lemmings than in other years. Predators that move over vast areas of tundra, such as snowy owls and jaegers, concentrate in areas where lemming populations are high. These predators are only able to nest successfully if lemmings are fairly abundant, and they raise more young when lemmings are numerous. Thus, many more lemmings are killed and eaten by predators during the population high. Predation, especially by weasels, may reduce lemming numbers when their populations are at low levels. However, scientists have found that all the predators and their young could not eat enough lemmings to cause the sudden crash in lemming numbers that occurs after a population high. Also, the low breeding success of lemmings after a population crash cannot be explained as an effect of predation. Thus, scientists agree that while predation can affect lemming populations, it is not the main cause of the lemming population cycles. (However, the rise and fall of predator numbers and populations is clearly a response to changes in lemming populations.)

The main cause of lemming population cycles is still debated. The effects of lemmings on the availability of minerals to plants has been suggested as one possible cause of population cycles. The roots of most plants penetrate only the top few inches of tundra soil due to underlying permafrost. Growing plants soon deplete the minerals in this shallow layer of soil. Tundra plants conserve minerals in their roots from year to year, but lose minerals when herbivores eat their leaves and roots. According to the mineral-cycling hypothesis, most of the minerals are transferred through food chains to lemmings and their consumers during lemming population highs. Lacking mineral reserves, the plants begin to produce leaves that contain fewer minerals. Lemmings need a good supply of calcium, phosphorus, and nitrogen to reproduce. If the plants they eat contain few of these minerals, the number of young produced could be reduced. Low reproduction, combined with intense predation, could cause a rapid population decline. A few years would be required for plants to restore their mineral reserves. But, once the minerals were again available, the plants should begin growing mineral-rich leaves and roots, and supply nutritious food for lemmings. The lemmings could then produce more young, and their populations would increase. This hypothesis, while interesting, has not been proven. Scientists who have tested it have found that cold summer weather can cause a greater drop in the mineral content of tundra plants than does grazing by a peak population of lemmings.

Stress from over-crowding may also be a factor. At very high population levels, lemmings may spend so much time fighting each other that they do not successfully raise young. Animals may also die from stress. Lower reproduction combined with higher death rates due to intense predation and stress could lead to a sudden population decline. Another hypothesis that has been advanced is that genetic factors governing lemming behavior contribute to the population cycle. At low population levels, lemmings that produce many litters may raise more young to breeding age. At high population levels, however, when food and space are scarce, lemmings that produce relatively few young, but provide these with exceptional care may be more successful. If reproductive behavior and litter size are genetically determined, and some evidence suggests they are, then changes in the genetic make-up of the lemming population, combined with predation, could cause the cycle.

Scientists have also found that when heavily browsed, some plants produce chemicals that are distasteful to lemmings. As lemming numbers grow, more and more of the available plants are browsed heavily, and may become inedible. Eventually there may be too few edible plants to go around. Undernourished lemmings produce fewer young, and are more likely to die from diseases, parasites, or the stress of overcrowding, in addition to starvation and predation. Thus, the production of distasteful chemicals by heavily browsed plants could also help account for lemming population declines.

Scientists still debate the relative importance of predators, mineral cycles, plant toxins, behavior, genetics, and other factors, such as weather. But most agree that dramatic changes in lemming populations result from a combination of interconnnections between lemmings and their environment. Undoubtedly, the population "cycles" of other animals are also caused by a combination of ecological factors.

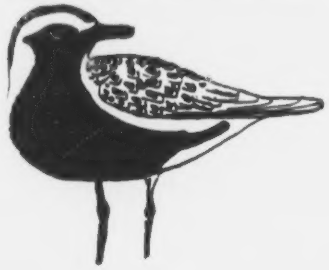
SYMBIOSES:

In addition to interacting through food chains and webs, many living things interact with and depend upon each other in other ways. When two kinds of living things "live together" or depend upon one another in some way, their relationship is called a SYMBIOSIS, or symbiotic association.

In some kinds of symbioses, both interacting species benefit from the association. The most striking example of mutualism in tundra ecosystems is provided by lichens. Many people mistakenly think that the lichens which cover much of the ground in many tundra areas are plants. Lichens are actually a combination of two organisms, a fungus and an alga or cyanobacterium, that live in a mutualistic symbiosis. The algae, which are capable of photosynthesis, manufacture food for themselves and the fungi. The fungi provide a protective shell that protects the algae from being dried out by the wind. In some cases the fungi may also help the algae obtain nutrients from rocks, the soil, or rain water by giving off acidic fluids that break down these surfaces.

Another good example of mutualism that is found in tundra ecosystems is pollination. Many tundra plants, like sedges and cotton grass, depend on wind to carry their pollen. Plants that are less common, or can grow only in specific sites on the tundra, must rely on insects to ensure successful exchange of pollen with others of their species. About 90 percent of alpine and over 60 percent of arctic tundra flowers are insect pollinated. (However, most tundra plants have back-up methods of reproduction, so they can survive even without pollination.) Bumblebees are one of the most important pollinators found in tundra ecosystems, but many insects, including butterflies, moths, mosquitos, and other flies are also important pollinators of tundra plants. The pollinators benefit from this association because the plants supply them nectar and pollen for food.

Other examples of mutualism include the connections between berry plants and berry-eating animals that carry their seeds, between nitrogen-fixing bacteria and certain legumes, and between mycorrhizal fungi and certain plants. In the latter two examples, the former organism helps the plant obtain needed minerals, while the plants provide sugars for their symbionts.



The term "commensalism" is used to describe symbiotic associations from which one species benefits, while the other is unaffected. For example, arctic foxes scavenge food from the kills of polar bears, brown bears, and wolves. These larger predators are unaffected--essentially they don't miss the scraps--but the foxes benefit from the food that they could not obtain on their own. Another example of commensalism is the relationship between golden or black-bellied plovers and other smaller shorebirds. Plovers nest on high spots on the tundra--frost boils, pingos, and ridges. Both the male and female plovers guard their nest and are very watchful for possible predators. Plovers give a loud warning whistle to warn their mate on the nest to be alert whenever they spot a predator. Other smaller shorebirds have been found to nest near plovers and to react when the plovers give an alarm call. By nesting near a plover, these birds gain a sharp-eyed guard for their own nests.

In a third type of symbiosis, one species benefits while the other is harmed. One of the most striking examples of parasitism is the relationship between warbleflies and caribou. These parasitic flies lay their eggs on a caribou's coat. When the eggs hatch, the larvae burrow into the caribou's skin and feed on the caribou's body fluids. When the larvae are fully grown, they burrow out and drop to the ground, where they eventually metamorphose into adult warbleflies. The warblefly larvae benefit from the food and shelter provided by the caribou, but the caribou suffer. Caribou under attack by warbleflies spend less time feeding and ruminating, and more time moving to avoid the flies. Severe harrassment by flies may result in caribou entering winter in poor condition, and ultimately reduce their survival and reproductive success. Many kinds of parasites occur in tundra, including fungi and insects that parasitize plant roots and many microscopic organisms that cause animal and plant diseases.

Introductory Activity 4.

Objective:

Students will become aware of the food chain and symbiotic connections among the living things in a tundra ecosystem.

Skills:

SCIENCE: comparing, inferring, predicting
LANGUAGE ARTS: reading, classifying, vocabulary building

Materials:

Tundra Puzzles (see following pages--cut out and laminate)

Procedure:

SUMMARY: Students will use information on the Tundra Puzzles to discover food chain and symbiotic connections among tundra organisms.

1. PREPARATION: Cut out and laminate the Tundra Puzzles.

2. STUDENT GROUPS SOLVE THE PUZZLES AND DISCOVER THE CONNECTIONS: Divide the class into groups of 6. Give each group a set of cards (the sets have matching numbers). Ask each group to read their cards and try to discover how the living and/or non-living things pictured are connected to, interact with, or need each other. The information provided should help them figure out how their puzzle fits together. Once a group has the puzzle together, they should check to make sure they understand each of the connections in the puzzle.

3. DISCUSS THE CONNECTIONS BETWEEN LIVING AND NON-LIVING THINGS. Write on the blackboard the following heading: "Living-Non-living Connections". Then ask the groups to raise their hands if they found any connections between living and non-living things. List these on the board. (Students should come up with the following: breathes air, drinks water, gets heat from the sun, makes food from air, water, and sunlight, gets minerals from the soil, and returns minerals to the soil). Discuss whether or not every organism is connected with or dependent on the non-living environment. Can students predict what living things would be affected if the non-living environment were changed? (All living things would be affected directly or indirectly.)

4. DISCUSS THE CONNECTIONS BETWEEN LIVING THINGS: Next, write the heading "Living-Living Connections" and ask students if they found any connections between living things. As they name the connections they found, help them group similar connections together. All the connections that involve one organism eating another should be placed in one group, and those connnections where one organism helps another should be placed in a second category. (If desired, the latter category may be further divided into "they help each other," "one helps the other," and "one helps, the other harms"--i.e. mutualism, commensalism, and parasitism.) After students have given examples that fit all these categories, tell them that scientists have given these ecosystem connections special names.

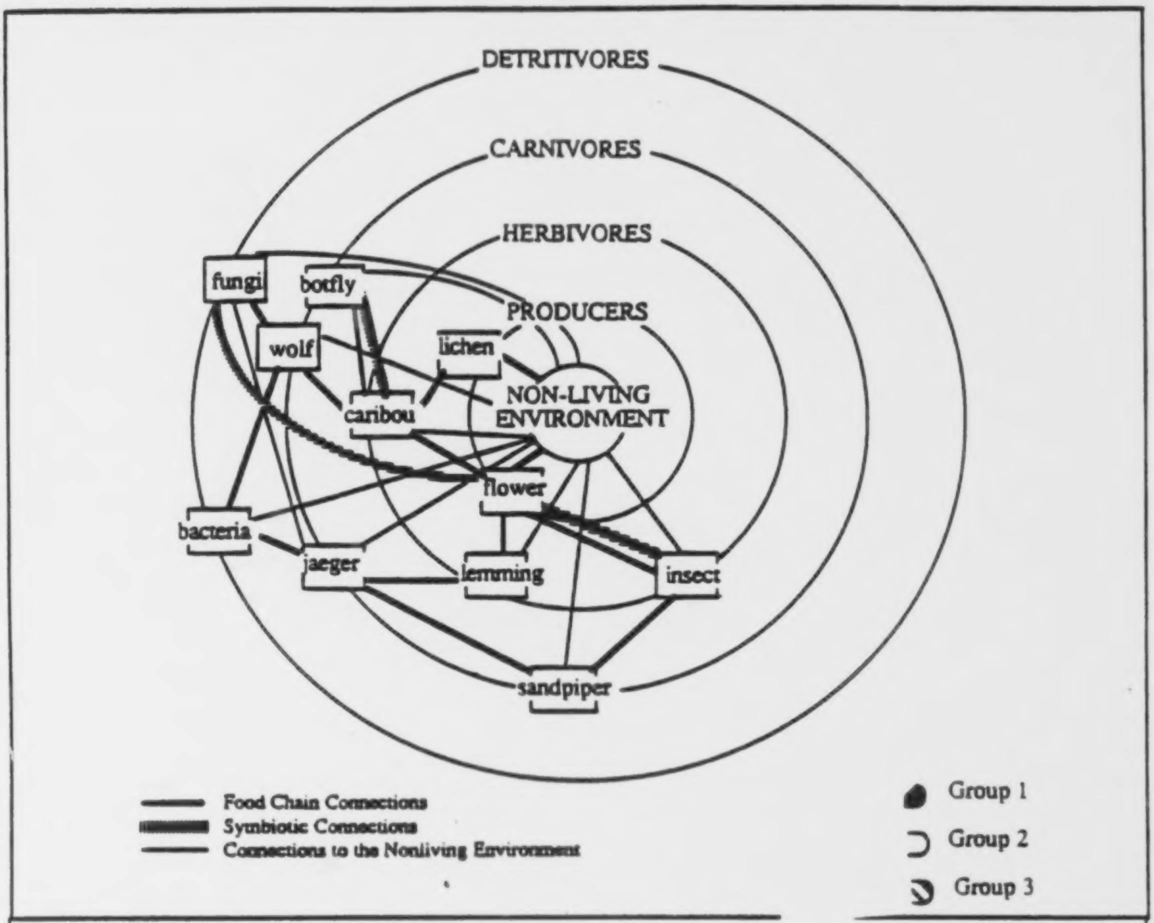
The first are called "food chain" connections. Explain how all living things are connected to others in the same community (or ecosystem) through food chains. Help students think of a complete tundra food chain. Be sure to include the non-living environment, a producer, herbivore, carnivore, and decomposer. Discuss the exchange of energy and minerals through food chains.

The second type of connections are called "symbioses" which literally means "living together." If desired, discuss the three types of symbioses, mutualism, commensalism, and parasitism. Discuss how symbioses connections differ from food chain connections. (They involve more than or something other than food.)

5. DISCUSS WHETHER ANY OF THE PUZZLES IS A GOOD REPRESENTATION OF AN ECOSYSTEM: Students should recognize that each puzzle actually shows just a few of the interconnections in an ecosystem, and that a picture of all the connections in an ecosystem would be incredibly complicated.

6. DISCUSS THE IMPLICATIONS OF ECOSYSTEM CONNECTIONS: Ask students why ecosystem connections are important. Ask them to name one kind of living thing that could survive if all other living things on earth died. (Challenge every answer with questions. The most likely student answers are 1) humans (Ask: What would we eat? Would we run out of breathable air (oxygen)?); 2) plants (Ask: What

Alaska Wildlife Week Unit 6. © 1988 Alaska Dept. Fish and Game


DETRITIVORES
CARNIVORES
HERBIVORES
PRODUCERS
NON-LIVING ENVIRONMENT
fungi
botfly
wolf
lichen
caribou
flower
bacteria
jaeger
lemming
insect
sandpiper
Food Chain Connections
Symbiotic Connections
Connections to the Nonliving Environment
Group 1
Group 2
Group 3

EXAMPLE SCORECARD

	Group 1	Group 2	Group 3
Cards Added(1 pt each)			
Food Chain Connections (1 pt each)			
Symbiotic Connections (3 pts)			

would the plants do after they used up all the minerals in the soil and water?); or 3) bacteria (Ask: What would the bacteria eat after all the dead material was gone, and what would they breathe after they use up all the oxygen?). Do students understand that no living thing could survive on its own, that all depend on other living things and the non-living environment? Discuss how various changes in an ecosystem might affect the living things present. What if all the plants died? All the mosquitos? All the bears? What if it didn't rain or snow anymore? What if the temperature got warmer? Can students predict that each of these changes, due to ecosystem connections, would result in changes in populations of many living things.

Extension:

Have students use the Tundra Wildlife Cards to discover more ecosystem connections and make a bulletin board or wall size diagram of all the interconnections they can find. The diagram above shows a possible format for setting up the display so that it is understandable. You might want to challenge groups of students to compete to findthe most connections. Have each group identify the connections they add to the display with a particular mark, then award points for each connection found. The group with the most points wins.

Evaluation:

Have students complete Worksheets 4a and 4b.

Tundra Puzzles

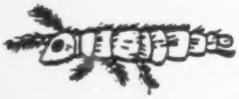
1

Soil

The soil contains minerals.

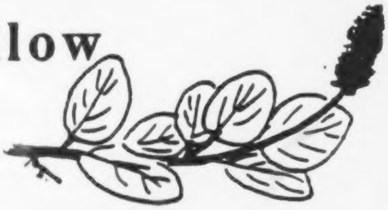
1

Springtail



Springtails return minerals to the soil. They feed on dead plants.

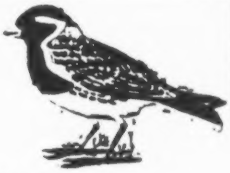
Willow



Willows make their own food using water, air, and sunlight. They take in minerals from the soil.

1

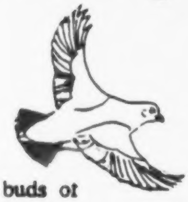
Longspur



1

Longspurs eat small insects, like springtails. They line their nests with ptarmigan feathers or caribou hair. This helps keep their eggs and chicks warm.

Ptarmigan



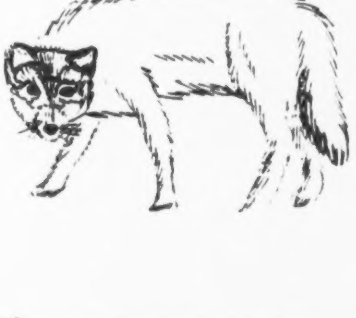
1

Ptarmigan eat the buds of willows and other plants.

Arctic Fox

1

Arctic foxes eat a variety of foods. They eat lemmings, small birds, ptarmigan, eggs, and scavenge dead animals.



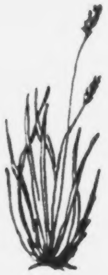
Sun

The sun provides energy in the forms of heat and light.

2

Sedge

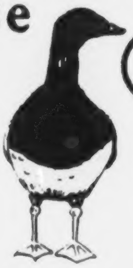
2



Sedges make food from carbon dioxide, sunlight, and water. They take minerals from the soil. They take some oxygen from the air, but return much more.

2

Goose

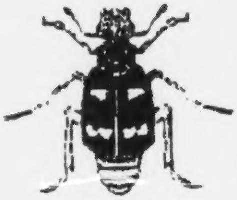


2

Geese eat grasses and sedges. They nest on an island in the middle of a lake or pond. They must have oxygen to breathe. Geese can keep warm, but only if it is not too cold.

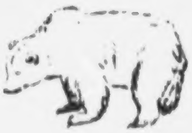
2

Carrion Beetle



Carrion beetles feed on any dead animal. They need oxygen to breathe. Beetles have a body temperature similar to their surroundings. They need heat to be active.

Brown Bear



Bears eat sedges and grasses, as well as berries, birds, mammals, eggs, and any dead animals they find. They need oxygen to breathe.

2

Air

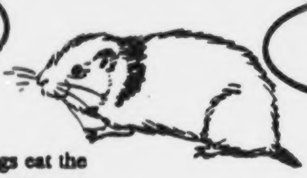
Air surrounds the earth. It is made up of nitrogen, oxygen, carbon dioxide, and other gases.

2

3

Lemming

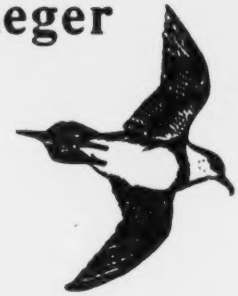
3



Lemmings eat the shoots, seeds, and berries of plants, including bearberry.

3

Jaeger



Jaegers feed on small mammals and small birds.

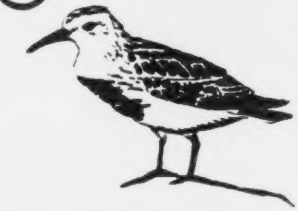
Bearberry

3

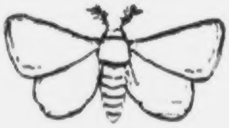
Bearberry makes food from air, water, and sunlight. They depend on mycorrhizalfungi to help them get minerals from the soil. This plant depends upon an insect to carry its pollen to other flowers.

3

Sandpiper



Sandpipers eat mainly insects, but they also feed on berries when insects are scarce.



Moth

Adult moths feed on nectar from flowers. They carry pollen from one flower to another.

3

Fungi

Fungi consume dead animals and plants as well as other waste materials.

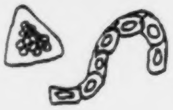
Bacteria

Bacteria feed upon and decay any dead material. Some kinds of bacteria live in the digestive tract of caribou and help them digest their foods. Other kinds live inside other animals and cause diseases. Bacteria require moisture in order to live.

4

4

Algae



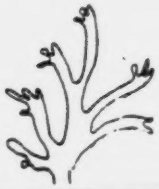
4

Algae make food from air, water, and sunlight. They can provide food to an organism that helps them. Algae must stay moist in order to live.

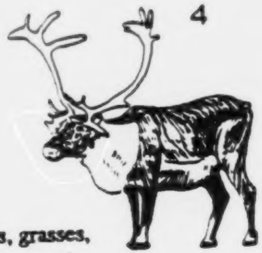
Fungi

4

Certain fungi live with certain algae. Together, they form lichens. The fungi prevent the algae from drying out. They need food.



Caribou



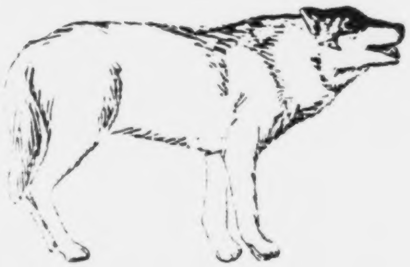
4

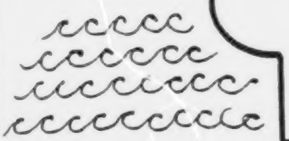
Caribou feed on sedges, grasses, herbs, and lichens. They need water to drink.

Wolf

Wolves feed mainly on large mammals, such as caribou. They need to drink water.

4





Water occurs in the air as clouds, in rain and snow, and on the earth in streams, lakes, and oceans.

Water

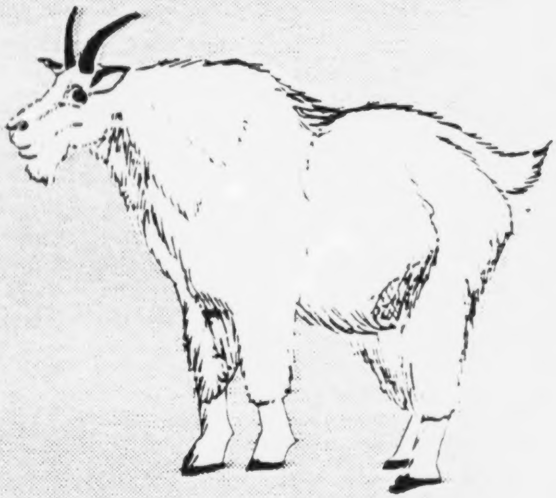
Food Chain Relay..............................
..............................Outdoors / Indoors
..............Physical Education / Science

OBJECTIVES: Students will become more familiar with tundra animals and food chain connections while practicing physical education skills.
SKILLS: running or other physical education skill; identification of living things and food chain connections
MATERIALS: Tundra wildlife cards, large room or playing area.
PROCEDURE:

1. Preparation: Divide the class into equal-sized groups of 5-6 students. Draw a starting line. Lay the tundra wildlife cards out on one side of a large playing area. Explain that the objective is for each team to attempt to put together a tundra food chain that includes the non-living environment, a producer, herbivore, carnivore, and detritivore.
2. Each student in each team must run (or skip, hop, walk) to the other end of the playing area and get one wildlife card to bring back to their group. The next team player can not leave until the previous player has returned with a card. The team may keep the card if it fits into a food chain, or is symbiotic with an organism on another card the team already holds. However, if the organism does not fit into their food chain, and is not symbiotic, it must be returned to the card pile by the next runner.
3. Whenever a team has a complete food chain, they yell out "Food Chain." If the food chain is complete and correct, their team wins 10 points plus 5 points for each symbiotic match they have. All the teams then return their cards to the card pile, and another round is begun.
4. If the food chain is incomplete or incorrect, the team loses 5 points, and the game resumes where it was left off. (To make the game more difficult, remove the cards in the winning food chain set constructed in each round.)

Food Chain Connections..... Indoors
.... Science

OBJECTIVES: Students will become more familiar with the living things in tundra ecosystems and their interconnections.
SKILLS: observation, inferring
MATERIALS: Tundra Wildlife Cards, Tundra Posters
PROCEDURE:
Students try to identify all the interconnections among the organisms shown in one of the Tundra Posters. They may work individually or in groups to identify the pictured organisms and their interconnections.



OBJECTIVES: Students will recognize that tundra ecosystems are less productive than other ecosystems because of the relatively slow rates of production and decomposition.
SKILLS: observation, inferring, predicting
MATERIALS: several bean plant seeds, potting soil, water, egg cartons or small pots, 2 grow lights, dark area, and warm and cold sites.
PROCEDURE:
Summary: Students will expose plants, and dead organic material (fruit) to various regimes of light and heat to find out the effects of light levels and temperature on plant growth and on decomposition. The instructions below are written so that an individual or group of students can do the experiments.

LIGHT AND PLANT GROWTH

1. Why do plants need light?

2. Based on your answer above, how do you think that the amount of light a plant receives will affect its growth. Do you predict that it will grow slower, faster, or at the same rate if it receives less light?

The following experiment will help you find out if your prediction was correct.

3. Divide 2 egg cartons in half, then fill each half with potting soil. Place one bean seed in each of the egg sections. Lightly water, then cover the soil with plastic. Place two of the carton halves under growlight #1. Place the other two under growlight #2. You will now control the amount of light received by the plants. Leave growlight #1 on throughout your school day. Turn it on in the morning, and off before you go home from school. Turn growlight #2 on when you arrive at school, but turn it off at lunch. That way, the plants under growlight #2 will receive only half as much light as those under growlight #1.

4. For the next two weeks, carefully observe the results of your experiment. Draw a picture of the plants in each carton, and measure their heights every other day.

5. Based on the results of your experiment, do you think arctic tundra plants grow faster or slower than plants in enviroments further south? The number of herbivores that can live in a given area depends upon the amount of food produced by the plants in the area. Which area do you think would have more herbivores living in it, a square mile of land at a high latitude, or a square mile of land at a low latitude? Explain your answer.

PRODUCTION, DECOMPOSITION, AND TEMPERATURE

1. Do you think temperature affects plant growth or the decay of organic material? If you do, how do you think the two are related? Write down your answer.

The following experiment will help you figure out whether your idea is correct.

2. Divide 2 egg cartons in half, then fill each half with potting soil. Place one bean seed in each of the egg sections. Lightly water, then cover the soil with plastic. Place two of the carton halves in the sunlight in a warm spot. Place the other two in the sunlight close to a cold window, or on top of a pan of ice. (If you place them on a pan of ice, be sure to replace the ice daily.)

3. Place a piece of an apple or a piece of bread in each of two plastic containers. Add a teaspoon of water to each container. Put the lids on both containers, then place one in a warm spot, and the other in a cool spot, such as a refrigerator.

4. Observe both your experiments carefully over the next 2 weeks. Record your observations every other day.

5. Based on your experiment, how does temperature affect plant growth and decomposition?

6. From your observations, what can you infer about the rates of plant growth and decomposition in tundra environments? Do these processes occur faster or slower than in warmer environments?

7. How might the rate of plant growth affect the number of animals that live in a particular environment?

8. How might the rate of decomposition affect plant growth, and the number of animals living in a particular environment?

9. Based on your observations and inferences, can you explain why tundra environments support fewer animals than other environments?

Lemming Cycles..............................Math / Science
..............................Indoors / Outdoors

OBJECTIVES: Students will recognize that changes in animal populations are caused in part by the many interconnections between living things and their environment.

SKILLS: teamwork, inferring, predicting, counting, graphing

MATERIALS: Large group of students or 40 cards with one symbol printed on one side, and another printed on the back; paper and pencil or blackboard and chalk

PROCEDURE:

SUMMARY: Students will play a game in which the class represents various trophic groups in a tundra ecosystem, and through a simulation, will learn how many factors can affect animal populations.

Step 1. This game begins simply, and becomes more complex as additional factors are added. Explain that the class is going to build a simple model of a functioning tundra ecosystem. Ask students what they need first in order to build a tundra ecosystem. They should guess the non-living environment. If students name organisms, ask whether the animal could survive without anything else in the ecosystem–what would it eat? How would a plant make food if nothing else was present? Explain to students that the supply of energy from the sun is constant, but the minerals in the soil, water, and air are limited resources. Of these, the minerals in soil are the resource in shortest supply in the tundra–so the first group of students will represent soil minerals.

Ask students what the next building block of an ecosystem would be? They should guess producers. Ask the rest of the class to represent tundra plants. Ask the two teams to stand in lines, with their backs to each other. Explain that on each round of the game, members of each team have a choice between two gestures--arms folded, or hands on their shoulders. Have each player make a gesture. Explain that you will soon have the teams turn around. When this occurs, each plant player must try to catch a mineral player who is making the same gesture.

A plant player can not catch a mineral player who is making a different gesture. Each plant must catch one mineral player in order to survive. Those plants who do not catch a mineral, die, return to the soil and become mineral players. Mineral players who are caught turn into plant players. Mineral players who are not caught remain minerals. Play a few rounds of this to see what happens to the plants and minerals. Assign 1 student to graph the changes in the plant population.

STEP 2. Ask students whether their model is a good representation of an ecosystem. They should recognize that their model needs some consumers. Assign one student to make a graph of the herbivore population. Divide the class in thirds and add a population of herbivores–for example, lemmings–to the model. Have the plant and minerals teams line up so their backs are towards each other. Then have the lemming team line up so their backs are towards the plants.

Ask the plant and minerals players to make one of the two gestures, then have the plants turn to face the minerals and again exchange the matched and unmatched players. These players must retain the gestures they made previously.

Have the lemmings make gestures and turn to face the plants. Plants that are matched by a lemming become lemming players. But, lemmings who do not find a plant match do not become plants; rather, they die and return to the soil as minerals–so they join the mineral team. Play a few rounds. The student who is making the graph should count the population after the entire round is complete (all teams have turned and matched).

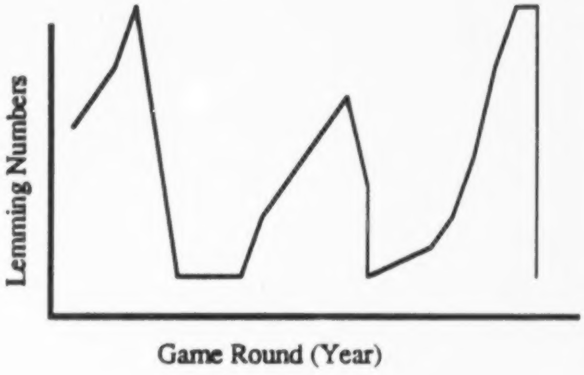
STEP 3. Repeat Step 2, but this time add a fourth team–predators. On each round, the plants and minerals match first and exchange, then the lemmings and plants, then the predators and lemmings. Play several rounds of this, then discuss the graphs that resulted and compare them to the previous graphs.

(continued on next page)

Alaska Wildlife Week Unit 6. Tundra. © 19 F&G

STEP 4. Ask students whether they now think their ecosystem model is fairly complete. Encourage them to recognize that, in fact, detritivores are needed to decompose the dead organisms and return minerals to the soil. Explain that on the next round, to correct this problem, those plants and animals that don't find a match and die, should go to a separate "holding area", rather than returning to the soil as minerals. For accuracy, separate detritivore teams might be needed for plant and animal remains--but to simplify matters its best to use only one detritivore team. Explain to students that just as there are many factors influencing lemming numbers, many factors affect detritivore populations. But, in tundra areas at least, cold temperatures, and wet acidic soil severely limit the activities of most detritivores, so the amount of dead material available is more than the detritivores can decompose. For this reason, the most realistic way to add detritivores to the game is to add a team of 2 players whose only role in the game is to move players from the holding area to the minerals team. Detritivores may only move one player at a time, but they can be active throughout each round. Play several rounds and graph the results. Discuss with students how the slow rate of decomposition in tundra could affect the other living things in the ecosystem. How mightthe availability of minerals in the soil ultimately affect lemmings and their predators?

STEP 5. The model above will now illustrates some of the inter-relationships among predators, prey, their foods, and the non-living environment. However, even this fairly complicated model leaves out some potentially important connections. For example, scientists have recently determined that plants which are grazed heavily begin producing distasteful chemicals that repel lemmings. The effects of this interesting connection can be simulated by having each plant and the mineral it catches function as a pair--by standing next to each other. Each member of the pair must give a different gesture. If only one member of the pair is matched, the surviving one may (on the following round only--assuming it gets a mineral match) make a third gesture (hands clasped) indicating that it is distasteful or inedible and can't be matched.



STEP 6. As a follow-up to this game, have students read the background information on Population Cycles from this packet.

VARIATION: If you do not have a large class, you may simulate the game using cards. Make up 40 cards with one symbol (X) on one side, and another symbol (*) on the other side. Assign one student (or a team of students) to represent each of the following: minerals, plants, lemmings, and lemming predators. Give each of the students 10 cards. Students place the cards on the table, varying the symbols that face up. The game is then played the same as described above, except that players place their cards face up, then match and trade cards among teams instead of signaling and moving themselves among the teams. In Step 4, assign one player to be a detritivore. In Step 5, place surviving plant cards in a sideline pile during the lemming--plant exchange portion of the next round. Have one student count and graph the lemming population after each round.

Credit: This game was inspired by the activity "Oh Deer!" from Project Wild.

Tundra Ecosystem Solitaire ....Science
Individuals / Groups...Indoors

OBJECTIVES: Students will become more familiar with tundra wildlife and ecosystem interconnections while playing a card game.
SKILLS: matching, identifying connections
MATERIALS: 1 set of Tundra Wildlife Cards--cut out and laminated, plus 10 additional cards showing the non-living environment.
PROCEDURE:
This game is intended for an individual student or small groups of students.

RULES FOR A SINGLE PLAYER

1. The object of the game is to turn all the cards face up and earn points by making food chains and symbiotic matches of the organisms shown on the cards.
2. Shuffle the cards and count out 5 piles of 8 cards each, face down. Turn over the top card in each pile.
3. Any non-living environment card or any detritivore card that is face up may be moved face up to form the base of a face-up pile above the other card piles.
4. Any face-up card that is connected to one of the other face-up cards (by a food chain or symbiosis connection) may be moved on top of the card to which it connects.
5. Whenever the top card is moved from a pile, the next card may be turned over.
6. If no other moves can be made, the player may count through the left-over stack. The player may try to play every third card. The player continues until he/she is unable to move any more cards, or turn over any new ones.
7. SCORING: The player sums up his/her score as follows: 1 point for each card in an incomplete food chain; 2 points for each symbiotic association. Ten points are awarded for each complete food chain that is compiled in one of the top piles (non-living environment- producer--detritivore).

RULES FOR TWO OR MORE PLAYERS

The object of the game is to turn all the cards face up and earn points by collecting food chains and symbiotic matches of the organisms shown on the cards.

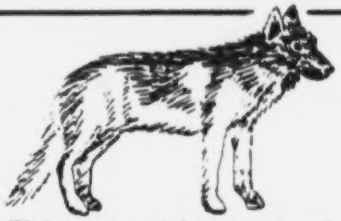
1. Shuffle the cards and count out 5 piles of 5 cards each, face down. Turn over the top card in each pile.
3. Any non-living environment card that turns face-up on the set-up is reshuffled into the deck and a new card from the deck is placed face up on that pile.
3. Each player gets to move the cards around on their turn only. He/she may move any card that is connected to one of the other face-up cards (that is on top). Either card may be moved on top of the other card it connects to.
5. Whenever the top card is moved from a pile, the next card in the pile is turned over.
6. If a player does not see any move, he/she may turn over one card from the shuffle deck. If he/she can not move this one, she/he returns the card to the deck and play passes to the right.
7. Whenever a non-living card turns up, the active player may collect it and begin collecting food chains and symbioses. He/she should place the non-living card face-up in front of them. He/she can then move cards from the central piles onto his/her non-living card to form a food chain (producer, herbivore, carnivore, detritivore). The cards must be moved in order. (A carnivore card cannot be collected until a herbivore and producer card are collected.) Also, if he/she finds a card showing an organism that is symbiotic with an organism in a food chain he/she has already collected, he/she may collect that card.

At the end of the game each player sums up his/her score as follows: 1 point for each card in the incomplete food chains they have built; for each complete food chain--3 cards-5 points; 4 cards--7 points; 5 cards-10 points; 6 cards-15 points; also award 5 points for each symbiotic association in a player's collection. Player with the most points wins.

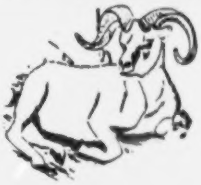
Worksheet 4a.
Alpine Connections

Name____________________________________

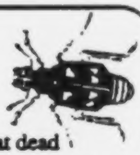
Use colored pencils to color the animals and their squares and to show the alpine tundra ecosystem connections. Color the squares of producers, green; herbivores, yellow; carnivores, red; omnivores, blue; and detritivores, purple. Use the same colors to connect each consumer to its foods. Draw black lines to show the symbiotic connections.



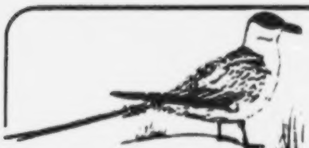
Wolves prey mainly on young and adult caribou and Dall sheep.



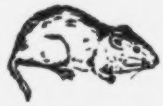
Dall sheep feed on grasses and other flowering plants of alpine tundra.



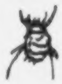
Carrion beetles eat dead animals. They don't notice if other tiny animals ride on their backs as they travel from one dead animal to another.



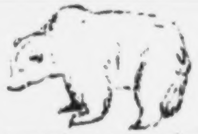
Jaegers prey on voles, horned larks, sandpipers, and other small birds.



Tundra voles eat grasses, berries, and fungi.

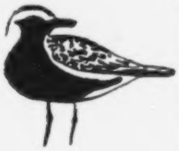


Mites are tiny animals that feed on dead animals. They need a ride to move very far.

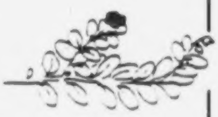


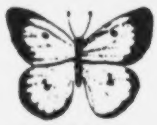
Brown bears eat grasses and other flowering plants, berries, voles, marmots, ground squirrels, and calves of Dall sheep.

Sandpipers eat a variety of insects, including butterfly larvae and beetles.

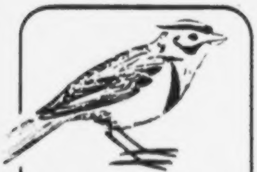


Cranberry plants make their own food. They need help getting minerals from the soil and an animal to carry their pollen.

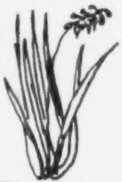




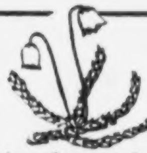
The larvae of this butterfly feeds on the leaves of flowering plants. The adults feed on nectar. They can carry pollen from one flower to another.



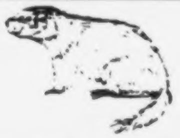
Horned larks eat butterflies, beetles, and flies while nesting. They also eat the seeds of grasses and other flowering plants.



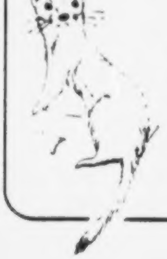
This tundra grass makes its own food.



Flowering plants make their own food. They supply nectar to animals that carry their pollen. They need help to get minerals from the soil.

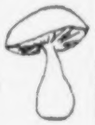


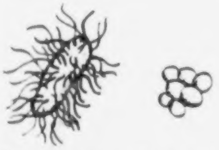
This marmot eats grasses and other flowering herbs of alpine tundra.



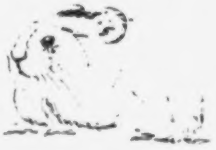
Weasels eat voles, pikas, and small birds such as horned larks and sandpipers.

This fungus feeds on dead plants and animal wastes. It returns minerals to the soil, but can also help plants take minerals from the soil.





These bacteria feed on dead plants and animals. They return minerals to the soil.

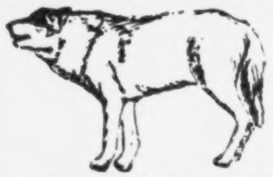


This pika eats grasses and other flowering plants of alpine tundra.

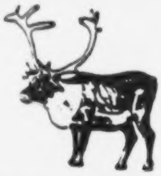
Worksheet 4b.
Tundra Connections

Name_______________________________________ Upper Elementary

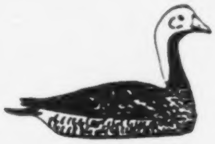
Use colored pencils to color the animals and their squares and to show the alpine tundra ecosystem connections. Color the squares of producers, green; herbivores, yellow; carnivores, red; omnivores, blue; and detritivores, purple. Use the same colors to connect each consumer to its foods. Draw black lines to show the symbiotic connections. (Hint: remember that a lichen is made up of two kinds of living things that live in symbiosis.)



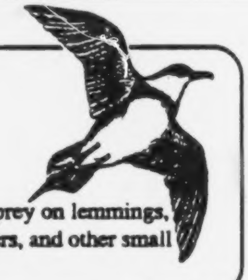
Wolves feed mainly on adult and young caribou.



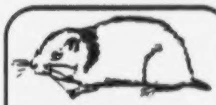
Caribou feed on sedges, other flowering plants, and lichens.



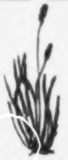
Emperor geese eat sedges and berries.



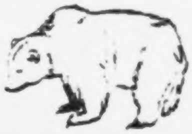
Jaegers prey on lemmings, sandpipers, and other small birds.



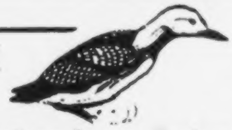
Lemmings eat sedges, other flowering plants, berries, and lichens.



Sedges make their own food.

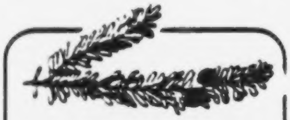


Brown bears eat grasses and other flowering plants, berries, lemmings, ground squirrels, and young caribou.

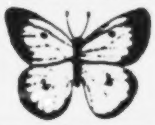


Arctic loons feed on a variety of small fish, including blackfish.

This fungi can supply a waterproof shell to the organism that helps it. It needs an organism that can make food.



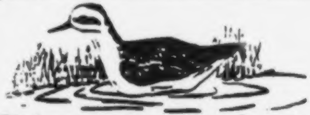
Crowberry makes its own food. It needs an animal to carry its pollen. It also needs an animal to scatter its seeds.



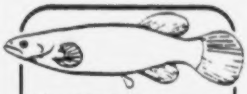
The larvae of this butterfly feeds on the leaves of flowering plants. The adults feed on nectar. They can carry pollen from one flower to another.

Cranefly larvae feed on dead plants.

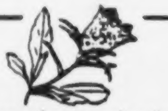
This algae makes its own food. It needs a shell to protect it from drying out.



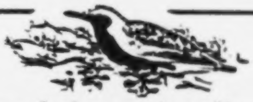
Phalaropes eat a variety of aquatic invertebrates, including cranefly larvae and mosquitos. Warnings of the approach of a predator can help them protect their nests.



Blackfish feed on a variety of aquatic invertebrates, including mosquito and cranefly larvae.

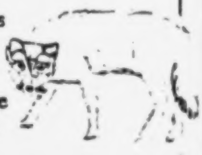


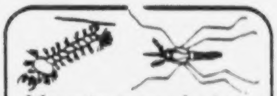
Flowering plants make their own food. They supply nectar to animals that carry their pollen. They need help to get minerals from the soil.



Plovers feed on a variety of insects, including beetles and cranefly adults. They also feed on berries. Plovers guard their nests carefully and give loud warning calls whenever a predator approaches.

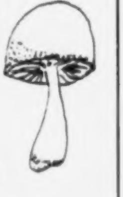
Arctic foxes eat lemmings, small birds, and the eggs of large birds. They also eat the scraps left by large predators, such as brown bears.

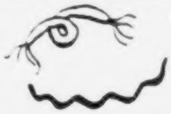




Mosquito larvae feed on dead plants. Adult males eat flower nectar, while the females feed on the blood of birds and mammals.

This fungus feeds on dead plants and animal wastes. It returns minerals to the soil, but can also help plants take minerals from the soil.





These bacteria feed on dead plants and animals. They return minerals to the soil.

Lesson 5

Vocabulary:

development, fragile, permafrost, productivity, resilient,

Objectives:

Students will recognize some of the problems of use and conservation of tundra wildlife and tundra ecosystems.

Teacher Background:

TUNDRA ECOSYSTEMS: FRAGILE OR RESILIENT? As human populations in tundra regions increase, and as our desires, abilities, and needs to develop resources found in tundra regions increase, humans are changing the tundra. Many scientists are concerned that we may inadvertently, and irreversibly damage tundra ecosystems and wildlife populations. In comparison to most other ecosystems on earth, tundra ecosystems appear relatively simple. Fewer species of plants, animals, and other living things are present, so there are relatively fewer ecological connections. This lack of complexity has led some scientists to conclude that tundra ecosystems are more fragile than other ecosystems, but it has also led other scientists to conclude that tundra ecosystems are more resilient.

Those who consider the tundra to be fragile point out that because there are few interconnections, changes in any single plant or animal population are likely to affect the entire ecosystem. These scientists argue that human activities that affect one tundra species are likely to indirectly affect many other species, just as, for example, natural changes in lemming numbers result in striking changes in populations of foxes, weasels, owls, and jaegers.

Scientists who consider tundra ecosystems more resilient than other ecosystems point to the wide oscillations in animal numbers that occur naturally, the ability of key tundra wildlife, such as lemmings, to reproduce rapidly, and the continued abundance of many tundra birds despite frequent years of nesting failure. These scientists think that since radical changes in animal and plant populations and production occur regularly, tundra ecosystems have a better built-in ability to absorb changes and continue intact than do other ecosystems.

Regardless of tundra's relative fragility or resiliency, however, most scientists agree that we must be cautious in our use and development of tundra resources, because the tundra is different from other ecosystems. Low productivity, the ease of overexploitation of animals, slow decomposition rates, the instability of permafrost ground, and the sensitivity of lichens to air pollution are points which are often raised.

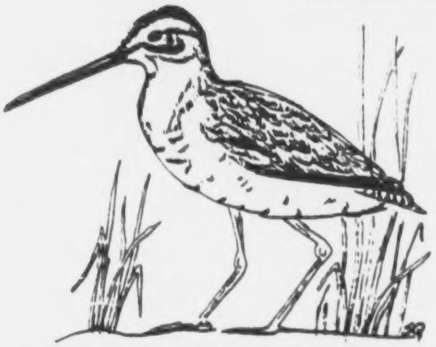
LOW PRODUCTIVITY: As mentioned in previous sections, tundra plants and lichens grow much more slowly than those in other ecosystems, primarily because the growing season is so short, but also due to the low angle of the sun and cool temperatures, both of which affect the rate at which photosynthesis can occur. Most tundra plants of any size are decades or, in some cases, centuries old, and most lichens are also quite old. When plants and lichens are removed by humans, or overgrazed by domestic animals or concentrations of wild animals, decades may be required for plants to become re-established on a site.

Most tundra wildlife also grow and reproduce slowly. For example, brown bears that live on the tundra of the Brook's Range do not breed until they are 8 years old, and then give birth to 2 young only every 4 years. In contrast, brown bears that live in the more productive coastal forests of southcoastal Alaska begin breeding when 4 years old, and have 2-3 young every 3 years. Although certain tundra bird species lay more eggs than related species in milder environments, their overall productivity is lower because they can nest only once each year, complete nesting failures are common, and they likely suffer higher mortality during their long-distance migrations. Some of the large fish found in some tundra ponds and lakes are now known to be 40 years old or more. In contrast, the same kinds of fish in other more productive environments may grow to similar weights in 20 years. Tundra fish such as the

These bare gravel sites do not provide the same camouflage or food supplies that natural dry tundra sites do. Additionally, gravel road beds and building pads interfere with the natural flow of water across the tundra. Water usually backs up along the upstream side of the pads. This floods formerly dry or moist sites, melts permafrost, and creates new depressions and ponds, thus changing a much larger area of tundra than the roads or pads themselves cover. Dust that blows off pads and roads also changes snowmelt patterns in surrounding areas. Finally, the huge amounts of gravel needed to build the roads and pads must be excavated from river beds and gravel banks. The extraction of gravel can affect water flow, turbidity, and other physical characteristics of rivers, thus upsetting fish migration and destroying overwintering and spawning habitat of fish. It also removes riparian (streamside) habitat that is important for muskoxen, caribou, ground squirrels, ptarmigan and other birds, as well as other kinds of living things.

VASTNESS AND VULNERABILITY:
To many people the vastness of lowland tundra is part of its beauty and wilderness value. Others feel that because the tundra covers such large areas, human activities do not have a significant impact on the tundra ecosystem. To an extent, both viewpoints are correct. Most tundra wildlife are forced to use large areas to obtain adequate food. The great caribou herds and wolves, their predators, wander over thousands of square miles. Tundra brown bears have home ranges of 100-400 square miles. Even fairly small birds like golden plovers defend territories measured in acres. Consequently, the densities of birds and mammals are low throughout most of the tundra expanses. Thus, even though buildings, airports, roads, and other human constructions may permanently change large areas of tundra and displace tundra wildlife, the actual numbers of animals displaced by individual projects is often small and seemingly insignificant.

Notably, tundra animals are concentrated at certain times and places, and disturbance of these sites may have serious consequences. For example, tens of thousands of caribou concentrate in relatively small areas for calving, and in insect relief areas during mid-summer; thousands of geese concentrate around large tundra lake systems to molt their wing feathers; hundreds of thousands of waterfowl and shorebirds concentrate in productive coastal tundra prior to fall migration; and tens of thousands of snow geese congregate in dry tundra of northern Alaska prior to fall migration.



On the other hand, the productivity of tundra ecosystems is a reflection of their vastness. Herds of 150,000-200,000 caribou could not survive if confined to a small tundra area; they would soon overgraze the lichens and other plants and die from lack of food. Nesting birds space themselves throughout available nesting habitat; those that are unable to find or defend a nesting territory simply do not nest. Hundreds of thousands of geese and ducks, and millions of shorebirds, nest in Alaska's wet lowland tundra expanses, making these among the most important bird nesting grounds in North America.

These impressive numbers reflect the vastness of the tundra more than its productivity. Reductions in the amount of tundra available for nesting will inevitably reduce the numbers and productivity of tundra birds.
Additionally, many nomadic tundra wildlife, such as snowy owls, jaegers, and arctic foxes, require vast areas of tundra because the conditions they need for successful reproduction and winter survival do not continuously occur at any one location. These species continually wander from one tundra region to another in search of suitable food supplies, and their numbers would likely decline if considerable areas of tundra habitat were disturbed or developed.

When we assess the productivity and value of the tundra we often think of the cumulative wealth and productivity of its wide expanses. In assessing human impacts, we must also consider the cumulative impacts of all development projects, recreational use, air pollution, and other human activities. Changes in tundra are long-lasting; areas disturbed 50 years ago have still not returned to their original states. Thus, while individual projects may have relatively little impact, the sum total of many projects conducted over a period of many years (or even decades), could significantly and permanently reduce the wealth of waterfowl, shorebirds, and caribou produced in Alaska's tundra ecosystems.

lake trout may reproducing until 10 years old, and then produce fewer eggs than fish in other environments. Populations of animals with slow growth and reproductive rates increase slowly, may decline rapidly if mortality (the number of animals that die) increases, and can only regrow slowly. Small increases in the number of animals that die can thus cause a long-lasting decrease in a population of tundra animals.

Evidence of the vulnerability of tundra wildlife populations is provided by fairly recent declines in certain populations of Alaskan wildlife as a result of overexploitation by humans. Muskoxen were completely extirpated from Alaska during the 1850's, and were it not for surviving populations in Greenland and Canada, the species would have become extinct. The western arctic caribou herd declined from 242,000 in 1970 to less than 75,000 in 1976. The number of wolves living on lands along the Dalton Highway (which parallels the Alaska oil pipeline) was greatly reduced during the 1970's. All of these wildlife population declines are thought to have occurred, at least in part, because too many animals were killed by humans. Humans kill animals for food, furs, sport, protection of life and property, and accidentally (by vehicles on highways, for example). Any population of wildlife will decline if more animals die than are born. Because most tundra animals are slow to mature, and produce few young relative to similar animals in milder environments, the harvest or killing of a relatively small number can cause a population decline (of some species). Tundra wildlife are also more easily overharvested because of the lack of cover--hunters can see them from long distances away.

SLOW DECOMPOSITION: Decomposition, or the breakdown of organic materials, occurs very slowly in tundra environments due to cold temperatures and the short season during which detritivores can be active. Chemical breakdown and weathering of inorganic materials also occur relatively slowly due to the extreme cold and low precipitation of most tundra regions. Consequently, litter and human wastes disposed of in tundra regions remain unchanged for decades and even centuries. Already many tundra areas are littered by disposable diapers, bags of human waste, abandoned oil drums, cans, plastics, and other materials. Unless this material is burned or physically removed by people, it will remain in place, and intact, for centuries.

Accumulated pollutants have more toxic effects than those that are widely dispersed. Because of the slow decomposition rates in tundra environments, air and water-borne pollutants often accumulate. Some tundra organisms, particularly fruticose lichens, are very sensitive to air pollution created by burning fossil fuels. Use of combustion engines in cars, planes, and snowmobiles, and burning of fossil fuels for heat or other uses creates air pollution. Although winds help disperse air pollution in some regions, temperature inversions can result in high concentrations of these pollutants. Additionally, winds may carry pollutants from industrial areas long distances to wilderness areas. Recently, scientists have discovered that some air pollution occurring in Alaskan arctic tundra may have originated in industrial areas of the Soviet Union and Europe.

PERMAFROST: Most of the tundra in northern and northwestern Alaska is underlain by permafrost and/or ice. Disturbance or removal of tundra vegetation reduces the vegetative insulation of the soil and results in permafrost melting. When permafrost in wet soil melts, the ground slumps, creating a depression. This depression fills with water during summer. The water absorbs heat from sunlight, which further melts underlying permafrost. In winter, the collectedwater freezes and expands. As it does so, it pushes surrounding soil out and up. Through repeated freezing and thawing and the eroding effects of wind and water the depression grows larger each year. Centuries of accumulation of organic matter may eventually insulate the soil again allowing permafrost to re-develop; only then will the tundra return to its pre-disturbance condition. Because of this long chain of events triggered by disturbance of tundra vegetation, human activities such as driving three-wheelers, snowmobiles, trucks, and particularly larger vehicles over the tundra create very long-lasting and easily visible scars on the land.

In recent years, engineers have prevented melting of tundra permafrost by leaving tundra vegetation intact and piling several feet of gravel on top of it to provide insulation below road surfaces and buildings. This method prevents permafrost from melting, but causes other changes in the tundra. Gravel road beds and building pads are similar to gravel river beds. They are sometimes used by animals that prefer dry tundra. However, few tundra plants can grow on bare gravel, so these pads will remain bare for decades.

Introductory Activity 5.

Objective:

Students will recognize that careless human activities can harm tundra environments and populations of tundra wildlife.

Skills:

MATH--addition, subtraction, or other math skills as instructor desires
SCIENCE: predicting
SOCIAL STUDIES: awareness that human activities change the environment and affect other living things

Materials:

Tundra Consequences Cards

Procedure:

SUMMARY: Students will list the activities of humans in tundra areas and predict the effects of these activities on the tundra; they will then solve math problems to match each activity to its consequence.

PREPARATION: The Tundra Consequences Cards have addition and subtraction problems on them. If you wish to change the size of numbers used or the type of math skill practiced, cross out the existing problems and write new math problems on each of the Tundra Consequences Cards. Cards with matching symbols must have math problems (same or different) that have the same answers.

1. DISCUSS THE TERMS: ACTIVITY, EFFECT, AND CONSEQUENCE.

a. Ask students to think of activities that people do in tundra areas. Use questions to help students list some of the following: hunting, fishing, walking, berry-picking, driving snowmobiles, three-wheelers, and other vehicles, flying airplanes, building roads and houses, disposing of litter and wastes, finding and retrieving oil, gas, and certain minerals. List these on the board under a heading "Human Activities".

b. Discuss the effects of one or two of these activities. For example, an effect of hunting is the removal of animals from a population, an effect of driving snowmobiles is snow compaction, an effect of driving three-wheelers is crushing and killing of plants, an effect of flying airplanes (or use of other vehicals) is air and noise pollution, and so on..

c. Ask students what might happen if too many people do the same activity, or are careless. How might the activity affect the environment, other people, or other living things over the long run? (For example, if people kill too many caribou, there won't be any left in the future.) Explain that the long term effects on the environment can be called consequences.

PLEASE NOTE:
Several of the Activity Ideas for Curriculum Integration in this lesson are experiments which can lead students to discovery of the effects of some human actions. Although it is not necessary, you may want to have students conduct these experiments before doing this activity. Have the class do (or begin) one experiment each day, over a period of 4-5 days. If time does not allow the class to do all the activities, select those activities which are most feasible for your class. The experiment with hunting and fishing effects requires about 20 minutes. The Moss Cover and Acid Rain experiments take 5-10 minutes to set up (excluding preparation) and then periodic checking by students (over a 5-day, and 1 hour period, respectively). The Snow Compaction Study and Signs of People activities each require 20 minutes (or more) outside. This introductory activity can then be used as a review and reinforcement of the concepts learned.

Alaska Wildlife Week Unit 6. © 1988 Alaska Dept. Fish and Game

2. PASS OUT THE TUNDRA CONSEQUENCES CARDS. Give each student 1 card. Explain that each card describes either a human activity, an effect, or a consequence of some human activity.

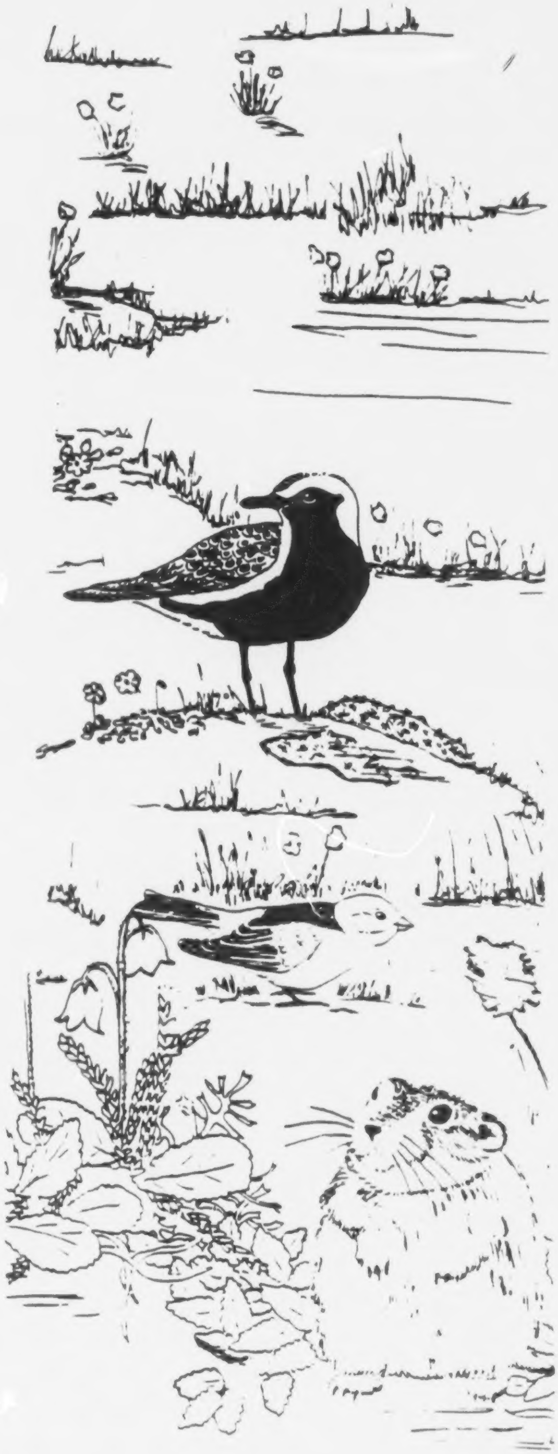
Students who get Activity Cards should use their knowledge of the activity to think of its effects and predict the consequences if the activity is uncontrolled. They should then try to find students with Effect or Consequence cards that describe some of the effects or consequences they predicted.

Students who have an Effect Card should try to think of a human activity that might cause the effect, or a consequence or change in the environment that the effect might lead to, if it were uncontrolled. They should then try to find students with matching Activity or Consequence cards. Students with Consequence cards should similarly think about the effects and activities that might cause the described consequence.

NOTE: SOME ACTIVITY AND EFFECT CARDS MATCH WITH MORE THAN ONE CONSEQUENCE CARD.

After most students have found an activity or consequence which they think matches their card, have all students turn their cards over and solve the math problem on the back. They can then determine whether they have matched correctly. Activities, Effects, and Consequences that match have matching answers.

3. STUDENTS DISCUSS THE CONSEQUENCES AND METHODS OF AVOIDING UNDESIRABLE ONES. Have each group of students list the activity, effects, and consequences which they found by matching the cards. Write these on the board. After each group has reported, discuss whether or not the consequence is desirable. Try to figure out ways of avoiding the undesirable consequences. Most adverse consequences can be avoided by reducing or controlling the human activities at the root of the problem. (For example, acid rain and its consequences could be avoided by reducing air pollution--by not wasting electricity, by using fuel-efficient vehicles, by recycling (to reduce pollution from processing of natural resources), by using more insulation, by walking rather than driving, etc.).



TUNDRA CONSEQUENCE CARDS

ACTIVITY 3 + 5 = ___ Humans drive vehicles across the tundra.	**EFFECT** 12 - 4 = ___ Crushes tundra plants	**CONSEQUENCE** 25 - 17 = ___ Tundra plants die, leaving the soil bare. This allows the underlying permafrost to melt, so the ground sinks.
ACTIVITY 19 + 5 = ___ Humans build houses, factories, and airports on the tundra.	**EFFECT** 13 + 11 = ___ Less tundra remains in its natural state. There is more noise and human activity.	**CONSEQUENCE** 31 - 7 = ___ Wildlife that require large spaces and are sensitive to disturbance move out of the area.
ACTIVITY 9 + 7 = ___ Humans disobey harvest regulations, so hunting of muskoxen and caribou is not limited.	**EFFECT** 5 + 11 = ___ Too many muskoxen and caribou are harvested.	**CONSEQUENCE** 56 - 40 = ___ Muskoxen and caribou become scarce.
ACTIVITY 34 - 6 = ___ Humans burn gas, oil, and coal to make electricity and heat.	**EFFECT** 21 + 7 = ___ The air becomes polluted with tiny particles.	**CONSEQUENCE** 43 - 15 = ___ Particles in the air combine with rain and snow and make these acidie. Acid rain kills lichens and soil bacteria.
ACTIVITY 13 - 2 = ___ Humans spray a pesticide chemical to get rid of mosquitos.	**EFFECT** 21 - 10 = ___ Populations of mosquitos and other insects get smaller.	**CONSEQUENCE** 33 - 22 = ___ Insect-eating birds, such as sandpipers, can not find enough food. Their populations decline.
ACTIVITY 14 + 5 = ___ Humans throw litter on the tundra.	**EFFECT** 27 - 8 = ___ The tundra is covered with litter.	**CONSEQUENCE** 81 - 62 = ___ Some animals become entangled in trash and die. Others die from eating pop can fliptops.
ACTIVITY 25 + 6 = ___ Humans obey harvest regulations for geese.	**EFFECT** 42 - 11 = ___ Some geese are killed, but others live and raise young.	**CONSEQUENCE** 94 - 63 = ___ The goose population remains healthy.
ACTIVITY 81 - 79 = ___ Humans put up fences across the tundra.	**EFFECT** 61 - 59 = ___ Migratory mammals like caribou are forced to spend more time in unfenced parts of the tundra.	**CONSEQUENCE** 51 - 49= ___ Caribou overgraze their range and many die of starvation. The habitat will not support as many caribou as it used to.
CONSEQUENCE 25 - 6 = ___ Water becomes polluted by chemicals leaking from discarded trash.	**CONSEQUENCE** 14 + 14 = ___ Caribou can not find enough lichens to survive winter. Many die of starvation.	**CONSEQUENCE** 56 - 28 = ___ Dead animals and waste materials do not decay. Minerals are not returned to the soil.

WILDLIFE AND HARVEST........... ....SOCIAL STUDIES / SCIENCE

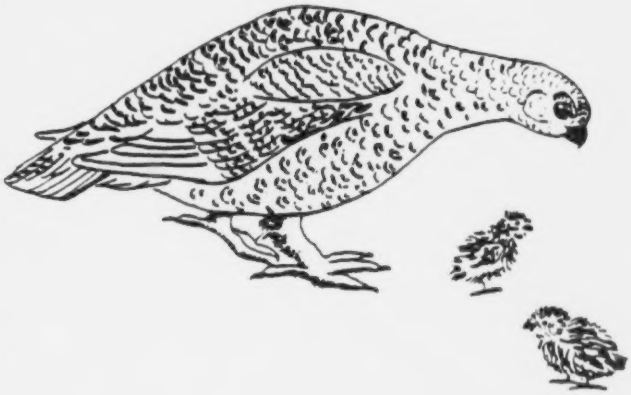
OBJECTIVES: Students will recognize that harvest of fish and wildlife must be limited to protect wildlife populations.
SKILLS: Counting, reasoning, applying scientific knowledge to a social question
MATERIALS: 50 cards showing a tundra animal that is harvested by humans (Photocopy one of the tundra wildlife cards); a number of slips of paper equal to the number of students in the class with 3/4 labeled "This is not a permit." and 1 of 4 labeled "Hunting Permit–You may harvest 1 animal." Additional slips of paper labeled: "This is not a permit. You harvest 2 animals anyway."
PROCEDURE:

Preparation: Tape a number of wildlife cards equal to the number of students in the class onto a tundra mural (made in an earlier activity, or just draw a simple sketch on the blackboard).

1) STUDENTS HARVEST ANIMALS: Ask students to pretend they are hunters or fishermen, and come harvest an animal from the tundra. Each student should come up and take one. Discuss what happened. Have students return the animals to the board.

2) STUDENTS RECOGNIZE THE NEED FOR LIMITS: Ask how the consequence of unlimited harvest could be avoided. Can students decide that humans must limit the number of animals they harvest. If humans do limit the harvest adequately, animals may survive to raise more young, and replace the animals that were harvested by people. Explain that is why hunters and fishermen must get a license and take only the number of animals that the license allows. If too many people want to harvest animals, we have to limit the number of hunters by only giving out a certain number of permits. The Alaska Department of Fish and Game does this in some cases by a drawing.

2. STUDENTS HOLD A "PERMIT HUNT." Have students count the number of animals on the board (in the population). Then, have each student draw a slip of paper from a jar. Only those who receive a harvest permit are allowed to take an animal. Ask the permittees to do so, then have all students return their slips to the jar. Then explain that half of the remaining animals are females, and they each produce one young the next spring. Place additional cards on the board to represent the young. Ask students to count the number of animals on the board now. (It should be the same as before.) Discuss why.



3. ILLEGAL HUNTERS TAKE EXTRA ANIMALS. Have students hold another permit hunt (but this time add the slips that instruct certain students to harvest illegally.) Repeat the above step--count number present, hold a harvest, show the results of animals reproducing, then re-count the number present. What happened? (The number should have dropped.) Can any students explain why there aren't as many animals as before? If desired, repeat this process 2 or 3 times to show the inevitable decline in the number of animals. Ask students whether or not they think it is important to obey hunting and fishing laws, and why. Do they understand the consequences of people not obeying the laws? (All the animals will eventually disappear.) Discuss why tundra wildlife populations are particularly susceptible to overharvest (see Lesson 5-Background Information).

The Effects of Snow Compaction.. ....Science / Social Studies

OBJECTIVES: Students will determine the effects of compaction on the value of snow as insulation by measuring and comparing the temperatures beneath compacted and uncompacted layers of snow.
SKILLS: Measuring, comparing, inferring
MATERIALS: thermometer, dip stick (see diagram)
PROCEDURE:

Preparation: Locate sites with compacted and uncompacted snow prior to class so you can take students directly to the sites when you go outdoors. .

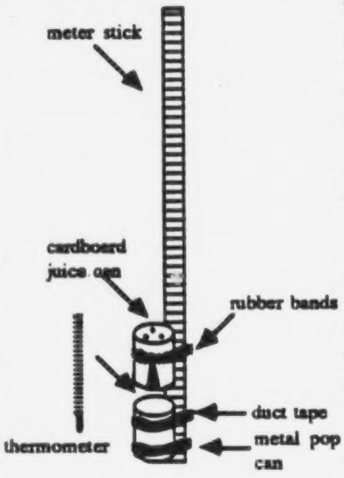
1. STUDENTS MEASURE THE DENSITY OF COMPACTED AND UNCOMPACTED SNOW: Students collect equal volumes (1 cup or so) of compacted and uncompacted snow. They melt these to determine which contains more water. (The compacted snow will.)

2. STUDENTS PREDICT THE EFFECTS OF SNOW COMPACTION ON THE TEMPERATURE UNDER THE SNOW. Encourage students to consider the fact that compact snow actually contains more water per inch of depth than uncompacted snow. Which would provide better insulation? Have the class vote and record the results.

3. DEMONSTRATE THE TECHNIQUE FOR MEASURING THE TEMPERATURE UNDER A LAYER OF SNOW.
a. The dip stick should be left outside for 30 minutes prior to using it.
b. Poke the end without the can into the snow and rotate it to create a hole large enough to stick the can in.
c. Remove the stick and turn it over so you can stick the can with the thermometer into the snow. Refill the hole with snow from nearby.
d. Record the depth of the snow from the meter stick.
e. Wait 15 minutes then pull the stick out of the snow, quickly open the thermometer case and read the thermometer.

2. HAVE STUDENTS MEASURE AND RECORD THE AIR TEMPERATURE.

3. STUDENTS MEASURE THE TEMPERATURE UNDER UNCOMPACTED SNOW. Take measurements from more than one location if possible. Students may want to measure the temperature under a snow drift, under snow in a sheltered spot, and in a windblown spot. Students should record the site description, depth of the snow, and the temperature measurement.



Thermometer Dip Stick
Materials:
1 cardboard juice can
1 aluminum pop can
1 meter stick
1 thermometer
1 rubber band
1 roll duct tape, strapping, or electrical tape.

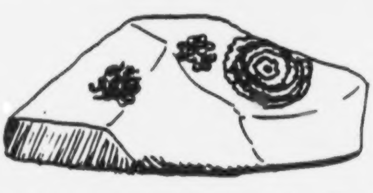
Instructions:
1. Remove 1 end from each of the cans, and punch holes in the other ends of them.
2. Tape the metal can to the base (0 end) of the meter stick with two bands of tape. The bottom of the can should be even with the bottom of the stick.
3. Cut a slit out of the side of the cardboard can so it can easily slide inside the metal can. Attach this can to the meter stick with a rubber band. It should be tight, but still moveable. It forms a moveable lid for the metal can. The thermometer should fit in the compartment formed by the two cans.

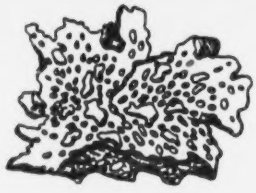
CREDIT:
The design for this thermometer dip stick is from OBIS, Outdoor Biology Instructional Strategies.

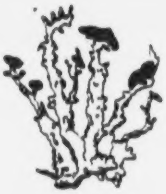
4. STUDENTS MEASURE AIR TEMPERATURES UNDER COMPACTED SNOW. Have students measure the temperature of the air under a snowmobile, three-wheeler or other vehicle trail, under a dogsled trail, and/or under a ski or walking trail. If possible, have students take measurements from several different sites. At each site they should record a description of the site, the depth of the snow, and the temperature measurement.

5. STUDENTS GRAPH RESULTS: Make a graph on the board showing temperature versus snow depth. Have students graph their results. Measurements from uncompacted snow should be recorded in one color, and measurements from compacted snow in another. Discuss the results. Which sites were better insulated (had the warmest temperatures)?

6. STUDENTS DISCUSS THE CONSEQUENCES OF DRIVING VEHICLES OVER THE TUNDRA. How might snow compaction affect plants and animals that live under the snow during winter? (It would reduce winter survival of these living things. The insulative value of a layer of snow may be reduced 100 percent by compaction.) Have students consider the effects of driving vehicles across the tundra in winter. How might the harmful effects be minimized?







Lichens and Acid Rain..Social Studies / Science

OBJECTIVES: Students will recognize acidity as a characteristic of solutions and will understand some of the causes and effects of acid rain.
SKILLS: Observation, use of a control, inferring, predicting, measuring pH.
MATERIALS: Two medium-sized pieces of foliose or fruticose lichens (all the same type, preferably a species of light coloration), 2 small pans, 2 plant spray bottles, many strips of pH paper, wood ashes, water, sunlight or a grow light, hand lenses. You may also want several other solutions for students to examine, including coca-cola, vinegar, ammonia, soda and water, and local rain or snow meltwater.

PROCEDURE:
PREPARATION: Before class, mix 1 tablespoon of wood ashes with 1 cup water and pour this into one of the plant misters. Label it Rain #1. Fill the second mister with distilled water and label it Rain #2. Set up a sunny, or grow-light lit spot for the lichen samples.
1. SET UP EXPERIMENT: Show students the lichen samples and ask them what they are. Discuss how lichens live. (By making their own food from air, water, and sunlight.) Where do they get minerals? (From rain water.) Explain that the class is going to do an experiment on lichen growth using 2 kinds of rain water. Place each of the lichen samples in a separate pan in a sunlit area (or under a grow-light); label them Lichen 1 and Lichen 2. Place the plant mister labeled Rain 1 next to Lichen 1, the plant mister labeled Rain 2 next to the Lichen 2. (Be sure it is clear which mister goes with which lichen, so students won't mix up their treatments.) Explain that students have the job over the next few days of watering (misting) the lichens with "rain" from the bottles. Lichen sample 1 should be misted only with Rain 1, and Lichen sample 2 only with Rain 2. Each day they should carefully observe (with a hand lens) and record any changes they see in the lichens.

2. STUDENTS BECOME FAMILIAR WITH ACIDS AND BASES: Allow the lichen experiment to progress for a few days until differences in the lichens treated with Rain 2 are noticeable. Then, without initially referring to the experiment, explain to students that solutions of water with other materials have a property we can't see, called acidity. Since we can't see the difference between an acid and a base (non-acid), we use a special type of paper called pH paper to measure the acidity of solutions. Demonstrate the use of pH paper--blue indicates a non-acid solution, while pink indicates an acid. Have students measure the pH of lemon juice, vinegar, water, and meltwater or rain from outside their school. (If desired, you can have students measure the pH of other solutions as well--e.g. soda and water, ammonia and water, coca-cola.) Explain that acids burn, or corrode other materials. (This can be demonstrated with an iron (not steel or galvanized) nail in a coke, or a square of chocolate in vinegar.) Explain that students have acids in their stomachs to help digest food.
Then, ask students if they have any idea why there was a difference in the two lichens after several days. (Can they predict it had to do with the water?) Which one do they think was acidic? Ask how many students have heard of acid rain. Do they know what it is? How might rain water become acidic? (Students may be able to reason that it gets something disolved in it.) Explain that acid rain is caused by air pollution.

Alaska Wildlife Week Unit 6. Tundra. © 1988 ADF&G

3. STUDENTS CONDUCT A SURVEY OF LICHENS AROUND THEIR TOWN: Have students look for differences in the numbers and kinds of lichens in different parts of town and away from town. Keep in mind that different kinds of lichens respond differently to air pollution. Fruticose lichens, in general, are most sensitive to air pollution while crustose lichens are more tolerant. Can they find any evidence of local air pollution problems? If possible, have students examine the lichens at sites in and outside town, near and far away from a power plant, and measure the pH of local ponds, rainwater, and snow.

4. STUDENTS DISCUSS THE POTENTIAL CONSEQUENCES OF AIR POLLUTION: Can students predict where they would find more lichens, near an airport or far away? Near a coal-fired power plant, or far away? In a town with automobiles, wood and oil stoves, or outside town? If tundra lichens die, how might this affect populations of caribou and other animals that eat lichens? What might happen to the populations of predators of these herbivores? What would happen to the soil if the lichens die? (Refer to the moss cover experiment.)

Explain to students that acid rain not only affects lichens, it can also kill fish (most can't tolerate a pH much less than 5). It can also kill the animals and other organisms that live in the soil, like bacteria. (This can be demonstrated using 2 samples of soil and fruit; treat one with "acid rain", the other with "normal rain". Observe the different rates of decomposition) Discuss how declines in the populations of these organisms would affect a tundra ecosystem. (Slower decomposition, less or no recycling of minerals, leading to lower plant production.) Acid rain also leaches minerals out of the soil. Just like an acid can corrode a nail, acid rain dissolves minerals. As the rainwater runs off into lakes and rivers, it carries the minerals with it.

5. STUDENTS DISCUSS WAYS TO REDUCE ACID RAIN. Considering the undesirable consequences of acid rain, how could humans reduce it? Discuss ways of reducing air pollution--by walking instead of driving, by not wasting electricity, by recycling (recycling aluminum reduces air pollution by 95% as compared to processing of new ore); by using and/or developing more efficient engines (e.g. cars that get 30 instead of 10 miles per gallon of gas), and by building super-insulated homes and buildings that require less energy to heat.

Vehicles and the Tundra........................ ....Social Studies / Science

OBJECTIVES: Students will recognize that vehicle traffic over the tundra damages vegetation and may result in melting of permafrost.

SKILLS: observation, predicting, inferring

MATERIALS: 2 equal sized baking pans, soil, water, freezer, moss and lichens (or several pieces of wool cloth, or bats of cotton to cover the pans), a desk lamp with an incandescent bulb or a window with strong sunlight

PROCEDURE:

Preparation: Mix up some potting soil and water and fill 2 pans with it, then freeze solid. Cover the surface of both pans with a thick layer of mosses and lichens (or cloth or cotton bats).

1. STUDENTS REVIEW THEIR KNOWLEDGE OF THE TUNDRA SOIL. Remind students that most tundra is underlain by permafrost, or perennially frozen soil, and much of the surface is covered by mosses and lichens. Show them the pans of frozen soil with the moss (wool or cotton) covering, and explain that these represent models of the tundra.

2. STUDENTS DISCUSS THE EFFECTS OF VEHICLE TRAFFIC ON THE TUNDRA. Ask students if they have ever looked at a tundra area where a vehicle has been driven. Was there any difference? If students do not know, use questioning techinques to help them realize that heavy vehicles crush and often kill the plants and lichens. Some vehicles also tear up the soil, and leave deep tire tracks. Ask students how this might affect the tundra?

3. STUDENTS OBSERVE THE EFFECTS OF REMOVAL OF THE MOSS LAYER. Remove the moss (wool or cotton) from one of the pans, and explain that the tundra area in that pan represents an area that was driven over by a large vehicle. Place both pans under an incandescent light (or in a warm, sunlit window) and ask students to observe what happens to the tundra "in summer when temperatures warm". (Caution: if left long enough, the frozen soil in both pans will melt. Be sure to have students observe them often and notice when the unprotected frozen soil thaws. Compare the soil in the two pans at that time.) Students should note that the unprotected permafrost melts first. Show students the photos on page 5 of the Tundra Wildlife Cards Supplement to this packet. Have students compare the photos. Besides melting the permafrost and changing the tundra, what other effects might the vehicles have? Have students predict the effects on lemmings, caribou, nesting birds, and plants.

Ask students to think of ways to minimize the damage done by vehicles. (Possible solutions: driving on the tundra allowed only in winter on thick snow, driving on the tundra never allowed; use vehicles with big tires that distribute the weight of the vehicle better; build roads with thick gravel beds that insulate the permafrost and then restrict vehicles to these roads.) If possible, have students go outside and look for evidence of the effects of vehicles on the tundra.

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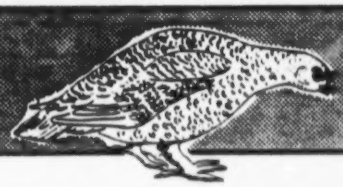

Tundra Posters........... ....Art / Social Studies .... Science

OBJECTIVES: Students will recognize that they and others can do things to help protect and conserve Alaska's tundra.

SKILLS: art, communication

MATERIALS: large paper, paints, crayons, examples of posters

PROCEDURE:

1. STUDENTS EXAMINE AND CRITIQUE POSTERS WITH A MESSAGE. If possible show students a variety of posters that were designed to advertise an event, inform people of a law, or the dangers of a certain activity. Have students discuss what they like or dislike about these, and whether or not they think the posters are effective in communicating their message. Discuss why.

2. STUDENTS MAKE THEIR OWN POSTERS TO ENCOURAGE OTHERS TO PROTECT THE TUNDRA. Explain to students that everyone must help conserve tundra wildlife and protect tundra ecosystems, but many people do not know that human activities can harm the tundra, or what they could do to help. Students can help solve this problem by making posters that explain ways of helping protect the tundra. Have each student make up a slogan and draw a picture for their poster. Their slogan may have two lines. The first line might say "Help Protect the Tundra (or tundra wildlife)." or "Don't Let --a given consequence--(Happen)" The second should describe what action people should take to prevent the consequence. (For example--obey hunting laws; stay on the road; recycle resources; walk, don't drive.)

EXAMINE THE ISSUES.. INDOORS..SOCIAL STUDIES / SCIENCE

OBJECTIVES: Students will become familiar with a current issue related to Alaskan tundra and recognize the importance of obtaining information on an issue before forming a decision.
SKILLS: collecting and gathering information, issue evaluation, decision-making
MATERIALS: Paper and pencil, magazines, newspapers, and other material related to a selected issue, two signs with the words "Agree" and "Disagree."
PROCEDURE:

1. STUDENTS SELECT AN ISSUE: A variety of issues exist relating to tundra areas of Alaska. Students should first identify an issue that relates to their local area, or one in which they have a particular interest by reading through local newspapers or by reviewing the following list. Have students vote on the issue they are most interested in finding out more about.

CURRENT TUNDRA ISSUES
–Oil and gas exploration and development in the Arctic National Wildlife Range*
–Opening of the Dalton Highway to the public
–Use of off-road vehicles in tundra areas by recreationists, miners, hunters, and others
–Waste disposal and water pollution at oil exploration camps, and in towns and villages in tundra areas,
–the effects of the pipeline and Prudhoe Bay
–Possible oil and gas development in the Colville River Delta
–Oil and gas leasing of the Teshekpuk Lake area (a goose staging area of international importance)
–Development of the Red Dog Mine near Kotzebue
–Goose management problems in the Yukon-Kuskokwim River Delta.

2. STUDENTS RESEARCH THE ISSUE: After selecting an issue, have students write one sentence describing their opinion of how the issue should be resolved. Place the "Agree" and "Disagree" signs on opposite sides of the room. Then read each student statement (group similar ones) and have students show their agreement or disagreement with each statement by standing near the Agree or Disagree sign. Record which resolutions of the issue receive the most agreement.

Next, have students determine the individuals and groups likely to have an interest, or position, related to the issue. Students should then write a letter to each of the interested parties to request information about their position. While waiting for replies, have students gather articles and relevant information from local and national newspapers and magazines. Students might also invite speakers to the class, or interview individuals with an interest or knowledge about the specific issue. Stress the importance of obtaining and examining information and viewpoints from all sides of the issue.

3. STUDENTS REVIEW OPPOSING POSITIONS: Have students read and evaluate the positions of all interested individuals and organizations. If desired, assign individuals or groups to role-play each of the interested parties. Then, hold a hearing on the topic.

Once again, have each student write a sentence describing how he/she thinks the issue should be resolved. Repeat the process of having students demonstrate their agreement or disagreement with each resolution by standing under the appropriate sign (in this step they represent themselves--not the group or individual they role-played). Compare the statements that received the most agreement this time with those that received the most approval before students researched the issue. Discuss why there is or is not a difference.

EVALUATION: Have each student write an essay stating what he/she thinks is the best resolution of the issue, what they see as the positive and negative consequences of their resolution (for people and tundra ecosystems), and how they would minimize the negative consequences. Students should demonstrate an understanding that any decision has both positive and negative consequences.

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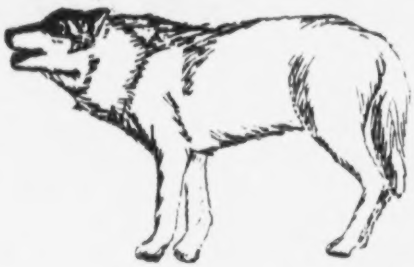
*At the time of this writing (1988), oil exploration and development in the Arctic National Wildlife Range is one of the most prominent issues relating to tundra ecosystems. Two groups on opposing sides of this issue have prepared videotapes stating their viewpoints and have made these available to the public at cost. Check-out copies are also available in some areas. These contrasting programs provide an interesting look at the Arctic National Wildlife Range issue and provide a good basis for class discussion of this topic.

For presentation of the oil industry's viewpoint, send $12.50 for a copy of "ANWR-Decisions for Tomorrow" to Alaska Oil and Gas Association, 121 W. Fireweed Lane, Suite 207, Anchorage Alaska 99503, ATTN: Ardie Merbs (available in 1/2 inch VHS only, 16 min.).

For presentation of an environmental organization's viewpoint, send $15.00 for a copy of "Arctic Refuge--Treasure of the North" (Specify VHS or Beta, 35 min.) to Northern Alaska Environmental Center, 218 Driveway, Fairbanks, AK 99701, ATTN: Video.

GEE WHIZ QUIZ.......................... ....LANG. ARTS, PHYS. ED., SCIENCE ....INDOORS / OUTDOORS

OBJECTIVES: The purpose of this game is to review this unit on tundra ecosystems.
MATERIALS: GEE WHIZ TUNDRA QUIZ (next page), large play area for game version 1.
PROCEDURE:
Game Version 1. Divide the class into 2 teams--the wolves and the muskoxen (or any other tundra animals). Mark a home base with a long strip of tape, or rope, at both ends of the room or yard. Assign each team to a home base. Have the teams stand in 2 lines facing each other midway between the 2 home bases. Then explain that the class is going to play a game in which they will use their knowledge of the tundra environment (which they just learned about in this unit), to guess whether or not the statements you make are true or false. If they think your statement is true, the muskoxen are to run toward their home base, and the wolves try to catch them. If the statement is false the wolves should run toward their base, and the muskoxen should try to catch them. Each team earns points for catching members on the other team--as long as they ran the correct (true or false) direction. Reiterate the instructions so that students clearly understand which direction to run. You might want to give some obvious true and obvious false statements as a trial run.



A TUNDRA CELEBRATION

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Celebrate the conclusion of this unit with a Tundra Treat. If you live in an area of tundra, you might try to involve students' families in making dishes from tundra plants and/or animals. If you live in a non-tundra area, you can still make a tundra dish--Cranberry Eskimo Ice Cream. The simplest mixture is to sprinkle berries with sugar, then mash with your fingers or a fork. Stir in canned milk or seal oil (Crisco will do). Wild berries are best, but you can use store-bought ones as an alternative. They are the same species as one of those that grows in tundra and muskegs of Alaska. Salmonberries or blueberries may also be used.

For more traditional recipes that incorporate tundra plants, obtain the reference: Nauriat Niginaqtuat, Plants That We Eat, by Anore Jones, Maniilaq Association

Credit: Idea contributed by Barbara Braley, Badger Road Elementary.

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Worksheet 5.

Gee Whiz Tundra Quiz

True or False?

________1. The tundra is hot.
________2. Snow helps keep the tundra soil warm during winter.
________3. Plants make food from sunlight and other non-living things.
________4. Pikas are a kind of mouse.
________5. Some insects sleep through winter.
________6. Marmots live in lowland tundra.
________7. Lemmings have babies during winter.
________8. Mosquitos are an important part of tundra ecosystems.
________9. It takes about 1 year for an orange peel to decay in a tundra environment.
________10. The tundra is a wasteland.
________11. In some places the ground is frozen 1000 feet deep.
________12. There are no birds that travel from South America nest in Alaska's tundra.
________13. On a wet site, the ground may sink if the tundra moss cover is taken away.
________14. A hundred thousand animals live in every square foot of soil on the tundra surface.
________15. Most plants could live just as well without fungi.
________16. Bumblebees get cold faster than other insects.
________17. Alaska's lowland tundra is some of the most important bird nesting habitat in North America.
________18. No animals can be frozen and still come back to life.
________19. The wind is not as strong at ground level as it is a few inches above the ground.
________20. The air helps keep the earth warm.
________21. Ptarmigan grow their own snowshoes.
________22. No lemmings turn white in winter.
________23. Tundra hares sometimes travel in large herds.
________24. Several Alaska marmots may crowd together in a single den during winter.
________25. A tundra plant has roots that go dozens of feet down into the ground.
________26. Some tundra is like a desert.
________27. Some lowland tundra areas are wetlands.
________28. Some of the oldest living things on earth live in tundra.
________29. Few living things occur in tundra.
________30. A tundra plant blooms when it is a few weeks old.
________31. Some tundra plants are only 2 inches tall when they are 50 years old.
________32. Snow buntings live on the tundra.
________33. There are no geese that live in lowland tundra.
________34. Lemmings have long tails.
________35. Some kinds of fish live in tundra lakes and rivers.
________36. The tundra is too cold for mushrooms to grow.
________37. A lichen is a plant.
________38. People can not live on the tundra.
________39. Humans can never harm the tundra.
________40. Tundra occurs on top of mountains.
________41. The tundra is a kind of ecosystem.

Reference List

The following references were used in preparing this set of teaching materials. They are listed according to subject to aid those interested in obtaining more information on the topics covered in this unit. Asterisked materials are those likely to be of most use to educators.

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TEACHING ACTIVITIES

Audubon Adventures. Audubon Month 1988 poster and leader's guide. "Alaska Tundra--arctic wilderness." Send $8.00 to Audubon Adventures, National Audubon Society, 613 Riversville Road, Greenwich, Conn. 06831

Alaska Department of Education. Ecosystems of the Great Land--Instructional Videos--Arctic and Alpine Tundra. Available from Alaska State Film Library. Video and teacher's guide.

Alaska Department of Fish and Game--Nongame Wildlife Program, Game Division. Alaska Wildlife Week Educational Packets. (Past units on wetlands, ecology, and wildlife populations contain activities and information relevant to the tundra theme.)

Alaska Sea Grant College Program. Alaska Sea and River Week Curriculum Series. University of Alaska Fairbanks. This excellant set of materials contains many activities useful for studying wet tundra ecosystems. Send for a list of guides and costs.

National Wildlife Federation. National Wildlife Week Education Packet. These materials cover a new theme each year, and include a poster, activities, and stickers. Write: National Wildlife Federation, 1412 Sixteenth Street, N.W., Washington, D. C. 20036

Outdoor Biological Instructional Strategies. Delta Education, Box M, Nashua, N.H. 03061. This excellant set of materials includes 97 activities for outdoor study and discovery. Send for information on costs.

Western Association of Fish and Wildlife Agencies and Western Regional Environmental Education Council. 1983. PROJECT WILD. Excellant activities relating to wildlife and wildlife conservation-national scope. *For information and training contact: Dolores Scott, Alaska Dept. of Fish and Game, Game Division, P.O. Box 3-2000, Juneau, AK 99802*

The following cross-reference of this Alaska Wildlife Week Teacher's Guide and Project Wild was provided by Dolores Scott

AWW	Project Wild
Lesson 1	Habitat Lap Sit - using tundra components
Lesson 2	Forest In A Jar - adding steps with freezing the jar with seeds or exposing it to wind
Lesson 3	Surprise Terrarium
	Rainfall and the Forest - use temp. instead of rain
	Adaptation Artistry
	Tracks
	The Thicket Game
Lesson 4	Interdependence
	Good Buddies - use arctic animal example
	Owl Pellets
	Muskox Maneuvers
	Oh, Deer (using geese or caribou)
	How Many Bears Can Live In This Forest - use tundra instead
Lesson 5	Planting Animals
	Who Lives Here
	Here Today, Gone Tomorrow
	Litter We Know

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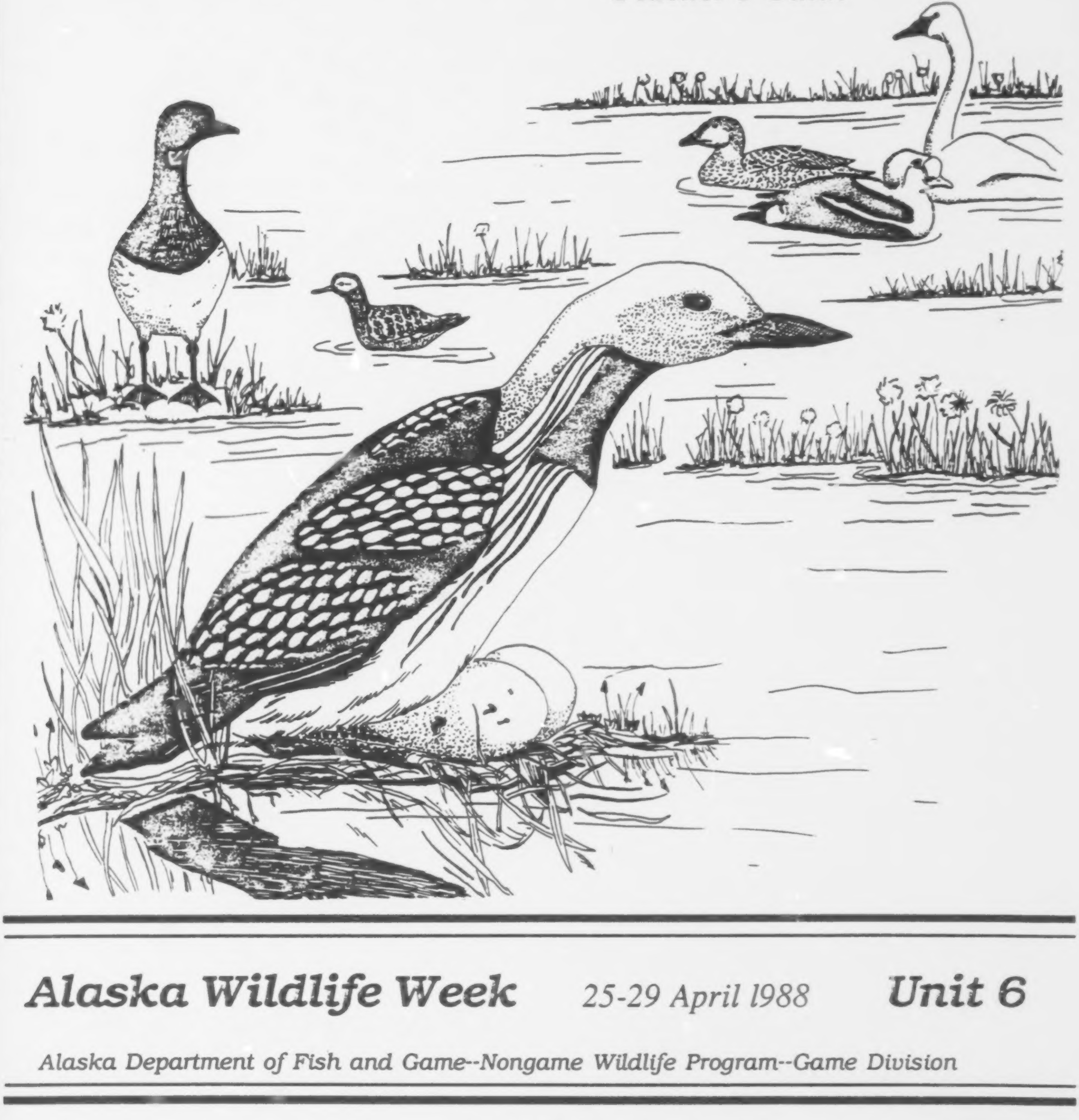
BEST COPY AVAILABLE

Alaska's Living Tundra

Junior / Senior High School
Teacher's Guide



Alaska Wildlife Week 25-29 April 1988 **Unit 6**

Alaska Department of Fish and Game--Nongame Wildlife Program--Game Division

Alaska Wildlife Week 1988
Unit 6. Alaska's Living Tundra

Educational Packet:
Teacher's Guide
Wildlife Photo Poster
Tundra Wildlife Cards
Alpine and Lowland Tundra Posters

Published by: Alaska Department of Fish and Game
Game Division--Nongame Wildlife Program

Written by: Susan E. Quinlan
Game Division--Nongame Wildlife Program
Alaska Department of Fish and Game

Illustrations by: Susan E. Quinlan

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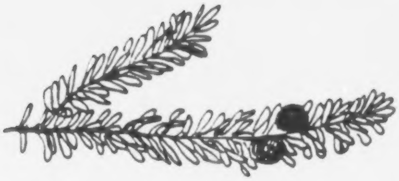

Introduction

Imagine a wetland that is really a desert. A place where animals find warmth on hills of ice. Imagine a place where 100 year-old plants are only a few inches tall. A place where billions of insects, millions of birds, and hundreds of thousands of mammals swarm, but where visitors often see nothing. Imagine an environment of contrasts. Imagine Alaska's tundra.

Many people think tundra is cold, barren, and desolate. Perhaps at first glance it is. On closer investigation, however, one finds that tundra environments are among the most fascinating in the world, and that a surprising variety of wildlife not only survive in tundra environments, but also flourish.

Discover this environment with your students as you use this **1988 Alaska Wildlife Week Educational Packet.** This comprehensive unit on **Alaska's Living Tundra** includes: **A Teacher's Guide**--full of background information on Alaska's alpine and lowland tundra environments, interdisciplinary activities, games, and worksheets; **A Wildlife Poster**--with color photographs of 12 species of tundra wildlife and two types of tundra; a set of **Tundra Wildlife Cards**--illustrations of and text about over 100 kinds of organisms that live in tundra environments; and **Tundra Posters** depicting many of the wildlife of Alaska's alpine and lowland tundra.

The Teacher's Guides are organized so that each of the 5 lessons on tundra builds upon those previous. An introductory activity is suggested for each lesson; use these along with any of the the wide variety of Activities for Curriculum Integration that are provided. The thematic approach of the packet is intended to help instructors integrate the study of tundra with regular classroom curriculums. All the activities are designed to help students develop or improve their skills and knowledge in science, social studies, language arts, math, and/or art. Easy-to-duplicate worksheets may be used to review, reinforce, or evaluate student understanding of the lessons in this unit.

Please feel free to adapt and modify activities and worksheets to best suit your teaching style, students' learning styles, and your location and situation. Three separate Teacher's Guides were prepared--one each for Primary (K-3), Upper Elementary (4-6), and Junior/Senior High School. Check to be sure you have the one that best matches your students' knowledge and thinking skills.

As always, we encourage you to integrate Alaska Wildlife Week with other conservation education materials available in Alaska. The Reference List at the end of this guide provides a list of many teaching materials relevant to this unit on Alaska's tundra. (This year, a special cross-reference to the Project Wild materials is included since many Alaskan teachers are also using those materials. See the information provided in the Reference List.)

The Alaska Department of Fish and Game began producing the Alaska Wildlife Week materials in response to teacher requests for Alaska-specific materials on wildlife and conservation. This project was orignally patterned after the National Wildlife Week educational effort sponsored by the National Wildlife Federation. **1988 marks the sixth year of Alaska Wildlife Week.** The theme for this annual celebration has changed each year, and a separate packet on each of six themes have been developed. You will find that the packets developed in previous years have some information and activities relevant to this year's topic. Check your school library for copies.

We hope you will use these materials during Alaska Wildlife Week in 1988, as well as throughout this and other years. Please send any comments or suggestions about this project to: Alaska Wildlife Week, Alaska Dept. of Fish and Game, Nongame Wildlife Program, 1300 College Road, Fairbanks, AK 99708

ALASKA WILDLIFE WEEK.

Junior/Senior High
Teacher's Guide

UNIT 6. Alaska's Living Tundra

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Lesson / Objective	Teacher Background	Introductory Activity	Ideas for Curriculum Integration	Student Worksheet
1. TUNDRA ENVIRONMENTS Students will learn about the distribution of cold environments.	7-10	11-15	16	17-19
2. THE LIVING TUNDRA Students will identify different types of tundra and the organisms present.	20-27	28	29-33	34-35
3. ADAPTATIONS OF TUNDRA LIFE Students will learn about the special traits organisms have to survive in tundra areas.	36-45	46-49	50-51	52-53
4. TUNDRA CONNECTIONS Students will learn about the inter-relationships between living and non-living things in tundra ecosystems.	54-58	59-63	64-66	67
5. HUMAN USE OF THE TUNDRA Students will recognize the human activities can affect the tundra.	68-70	71-77	78-82	83

Supplementary Materials That Accompany This Teacher's Guide

A Color Poster

Color photographs of Alaska'a lowalnd and alpine tundra and 12 kinds of tundra wildlife

Tundra Wildlife Cards

Over 100 illustrated cards of common tundra wildlife of Alaska,including birds, mammals, insects, invertebrates, fungi, plants, and microscopic organisms.

Adaptation Cards

Thirty-two illustrated cards with information about animals and their adaptations to various environments.

Alpine and Lowland Tundra Posters

A large poster depicting life on alpine and lowland tundra.

Worksheet Answers

See page 6 for the solutions.

Worksheet 1a. As latitude increases, the elevation at which treeline occurs decreases. In other words, alpine tundra occurs at lower elevations at high latitudes. A 10 degree increase in latitude results in an approximate 100 feet drop in the elevation of treeline. The southern edge of lowland tundra is actually not defined by a certain latitude, but rather by a combination of latitude and local climate. However, for the purposes of this worksheet, students should have predicted between 65 and 70° latitude.

Worksheet 1b. Driest: tundra, desert. Wettest: tropical forest, boreal forest; Coldest: tundra, boreal forest; Hottest: desert, tropical forest; No cold season--desert, tropical forest; The locations on page 1 are 1-Barrow, 2. Kotzebue, 3. Bethel, 4. Cold Bay. All are locations where tundra occurs. The variation in the climates of these four sites should help students recognize that Alaska's lowland tundra varies. Lowland tundra in more southern areas has a greater variety of plants and animals than tundra in northern Alaska.

Worksheet 2a. The following words were included in the puzzle: air, arctic, arctic fox, arctic loon, blackfish, botfly, bumblebee, caribou, cold, cool, cranefly, eider, goose, high latitudes, ice wedge, jaeger, lemming, lichen, longspur, long winters, lowland, migrants, mosquito, moss campion, muskoxen, northern, oldsquaw, permafrost, phalarope, pingo, plover, polygon, sandpiper, short summers, shrew, snow bunting, snowy owl, soil, springtail, sunlight, treeless, tundra hare, water, weasel, wetland.

Worksheet 2b. The following words are hidden in the puzzle: air, Alaska, alpine, brown bear, caribou, cliffs, cold, dall sheep, dry, dryas, fungi, golden eagle, gyrfalcon, high elevations, horned lark, lemming, lichens, long winters, lousewort, marmot, migrants, mosquito, mountain goat, moutainous, permafrost, pika, polygon, ptarmigan, rocky, sandpiper, short summers, singing vole, soil, springtail, sunlight, talus slopes, treeless, water, water pipit, weasel, wheatear, whimbrel, windy, wolf, wolverine.

Reading Comprehension Worksheet: 1. hibernating, 2. all of these, 3. a place where birds gather before migrating, 4. true, 5. true, 6. all of these, 7. by stopping all growth and activity; 8. true, 9. true, 10. by living off stored hay, 11. true, 12. false, 13. hair, wax, and dead leaves, 14. true, 15. they make antifreezes, 16. true, 17. false, 18. true, 19. false (no sun to heat up the dark coloration), 20. true.

Worksheet 3b. Bird Migration: self-explanatory

Worksheet 4. Lemming Connections with the Non-living Environment: Lemmings need air to breathe, water to drink, and soil to dig their burrows in during summer. They need the sun to keep their environment relatively warm. By digging burrows in the soil, they aerate it and allow the soil to soak up more water. Lemmings need snow cover to survive winter and the depth and type of snow can affect their survival. By removing plant cover from the tundra, they may affect permafrost depth. They are also indirectly involved in the mineral cycle; by tearing up leaves, lemmings speed up their decomposition and the return of minerals to the soil

Food Chains: non-living environment (sun, air, water, soil) -- producer (sedge, willow, berry-producing plant, lichen)--lemming--jaeger, owl, fox, weasel--fungi, bacteria; add an insect as a herbivore to complete the third food chain example;

Symbioses: Mutualism--plants and lemmings are interdependent, indirectly. Lemmings speed recycling of minerals, which helps plants; plants are food for lemmings. They also aerate and fertilize the soil.

Commensalism: lemmings use muskoxen hair or ptarmigan feathers as insulation in their burrows (lemmings benefit, others unaffected). Seeds entangled in lemming fur get carried to new areas where they may grow--(plant benefits, lemming unaffected)

Parasitism--certain lice, fleas, worms, and bacteria are parasites of lemmings; adult female mosquitoes may also be considered parasites of lemmings.

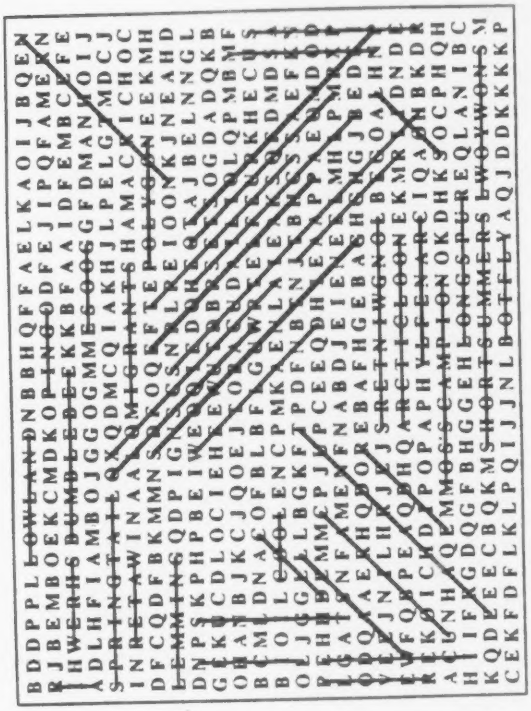
Worksheet 5. Gee Whiz Tundra Quiz: 1. T, 2. T, 3. T, 4. T, 5. T, 6. T, 7. F, 8. T, 9. T (wheatear), 10. T (if it is ice rich (wet) soil, 11. T (some pingos are formed when large lakes drain), 12. T (mites, springtails, etc.) 13. T (an estimated 90% of all Alaskan plant species need mycorrhizal fungi), 14. T (as long as some ledges are available), 15. T, 16. T (rotifer, tardigrade, some insects, wood frogs, blackfish--if only partially frozen), 17. T, 18. T (it also helps keep it cool by reflecting sunlight), 19. T, 20. T (collared lemming), 21. T, 22. T, 23. T , 24. F (they may go dozens of feet horizontally, but not vertically due to permafrost), 25. T (some tundra areas receive less precipitation than desert), 26. T (much of the lowland tundra is a wetland, because permafrost prevents rain and snowmelt water from seeping into the soil; 27. T (lichens), 28. F (fewer than in more productive environments, but still a great number), 29. T (some willows in sheltered sites, such as snowdrift sites), 30. T (most are 2 years or more), 31. T, 32. T, 33. T (pikas), 34. T, 35. T, 36. T, 37. T, 38. T (it may be 2500 feet thick), 39. T (Barrow, for example), 40. T, 41. T, 42. T, 43. F (it is less productive than most), 44. F (they are very important in tundra ecosystems), 45. F (pingos, polygons, frost boils, etc. all contribute to the relief of lowland tundra, 46. T (they rely on their fur to keep them warm and are less active in winter than in summer when they are raising young).

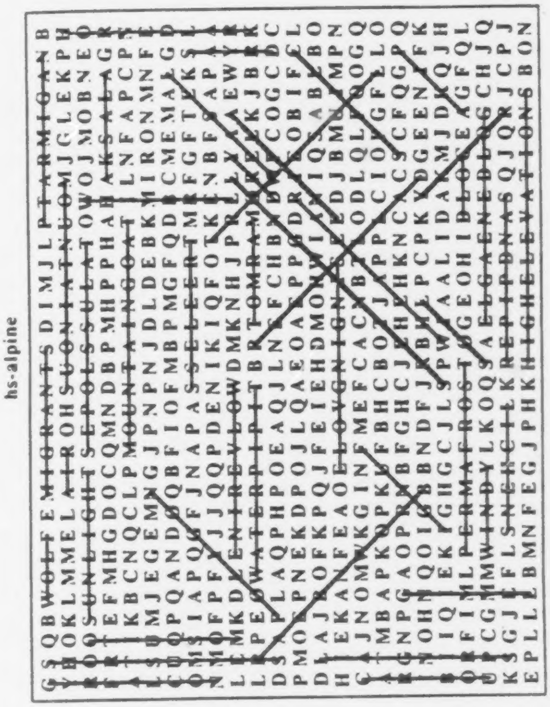
A Tundra Glossary

active layer	the layer of soil, lying on top of permafrost, that thaws and re-freezes each year
adaptation	a trait that enables an organism to survive in a particular environment
alpine tundra	periodically cold, treeless environments that occur at high elevations throughout the world
animal	living things in the Kingdom Animalia; one of the 5 major groups of living things that includes invertebrates (insects, crustaceans, worms, echinoderms, etc.) and vertebrates (birds, mammals, fish, amphibians and reptiles) Animals have a highly organized cell structure; most move from place to place, and all are consumers.
antifreeze	a compound that lowers the temperature at which water, or another liquid (such as sap, cell fluids, or blood) freezes
carnivore	a consumer that mainly eats other consumers; "carnivore" literally means meat-eater, and is usually applied to animals such as wolves, but organisms that eat mainly insects are also carnivores, since insects are consumers.
commensalism	an interaction between two species from which one species benefits and the other is unaffected
consumer	any living thing that gets energy and minerals by eating (consuming) other living or dead things
decomposer	an organism that breaks down dead organic material, thus returning minerals to the non-living environment (includes some micro-organisms that break down dead material without consuming it.)
detritivore	any consumer that ingests wastes and/or the remains of living things that have died; detritivores are a type of decomposer
dormancy	a period of inactivity, in which some or all life processes slow down or stop
ecosystem	all the non-living and living things and their interactions in a specific area
elevation	the height of the ground above sea level
energy	the force that causes objects to move; energy occurs in several forms including in light, heat, and stored in chemical bonds
environment	all the non-living and living things in a particular place
food chain	the pathway of energy and minerals from the non-living environment through producers and consumers back to the non-living environment
food web	all the inter-connected food chains within a particular ecosystem
frost boil	an area of bare soil up to several yards (meters) in diameter caused by repeated freezing and thawing of soil
fungi	one of the 5 major groups of living things. Most fungi do not move around, but instead, live their lives in one place. Most obtain minerals and energy from dead things and waste materials, but some obtain food through symbioses with plants or microscopic organisms. This group includes mushrooms, toadstools, shelf fungi, molds, yeasts, and rusts. (Slime molds are sometimes classified as fungi also.)

herbivore	a living thing that feeds on producers, such as plants, algae, or lichens
hibernation	a period of inactivity, in some mammals, during which all life processes (breathing, heart rate, body temperature, etc.) are reduced; an adaptation to avoid periods of cold and scarce food.
ice wedge	a wedge-shaped lens of pure ice in permafrost soil, caused by a crack in the permafrost that accumulates meltwater during summer; as the accumulated water freezes, an ice wedge grows. Ice wedges are the cause of polygonal ground in lowland tundra
insulation	anything that reduces the movement of heat energy into or out of a particular object or area
irruption	a sudden, large increase in the population density of a particular species in a given area
latitude	a measure of the distance of a given point on earth from the equator
life cycle	the birth, growth, reproduction, and death of a particular kind of living thing
living things	something that is able to move, grow, and make new things like itself; an organism. LIving things are classified into 5 major groups: animals, plants, fungi, monerans and protists.
lowland tundra	the cold, treeless environment found in the arctic and maritime subarctic
migration	a regular, seasonal movement of an animal from one place on earth to another
moneran	one of the 5 major groups of living things; includes only microscopic organisms, including bacteria and cyanobacteria (formerlly called blue-green algae). The cells of monerans do not have a nucleus.
mutualism	an interaction between two species from which both benefit; a type of symbioses
non-living	Something that does not, and cannot, move, grow, or make new things like itself; air, water, soil and rocks, and energy are the non-living things found in all ecosystems
parasitism	an interaction between two species from which one, the parasite, benefits, and the other, the host, is harmed; a type of symbiosis
omnivore	a consumer that eats both producers and other consumers
permafrost	perennially frozen ground that may or may not contain ice. In the arctic tundra permafrost may extend 2,240 feet (700 m) below the surface
pingo	an ice-filled hill on the tundra, sometimes 230 feet (70 m) or more high and 2000 feet (600 m) in diameter; a pingo may be circular, oval, or irregular in form
plants	One of the 5 major groups of living things; includes mosses, ferns, horsetails, conifers and flowering plants; this group is characterized by having cell nuclei and cell walls, a highly organized arrangement of cells, most can do photosynthesis and are important producers; most are green, and all except mosses and liverworts have a specialized system for transport of water and minerals, including roots, stems, and leaves.

polygons	one of the forms of patterned ground characteristic of soil subject to intensive frost action; many polygons are formed by ice wedges; polygons with sunken edges are called high center polygons; those with raised edges and a sunken center are called low center polygons
population	all the animals of a particular species that live in a particular area and interbreed
producer	any living thing that can convert non-living materials (air, water, and light) into food for itself and other living things; plants and algae are examples of producers
productivity	the amount of new growth, or number of young, produced per year or other unit of time
protists	any living thing in the Kingdom Protista, one of the 5 major groups of living things that includes some microscopic living things (algae and protozoans) and kelp or seaweeds; organisms in this group are characterized by their cell structure, which includes a cell nucleus, and by the lack of cell specialization for specific purposes
symbiosis	an interaction between two species in which at least one species depends upon the other
tundra	the windy, treeless, and periodically cold environments that occur at high latitudes and at high elevations
tussock	a small mound formed by certain tundra grasses that continually retain their dead leaves; walking is difficult across tussock tundra; tussocks are used by many kinds of insects and other tundra wildlife





Lesson 1.

Objectives:

Students will be able to describe the main characteristics of tundra environments: the absence of trees, long cold winters and short cool summers. They will be able to explain why tundra occurs at high elevations and northern latitudes.

Vocabulary:

alpine, atmosphere, climate, elevation, environment, energy, latitude, permafrost, temperature, tundra

Teacher Background:

WHAT IS TUNDRA?
The word"tundra" is derived from a Finnish word "tunturi" which means completely treeless heights. The absence of trees is an important characteristic of tundra, but deserts, prairies, and most wetlands are also treeless. The term "tundra" is used to describe the treeless ecosystems that develop in areas with long, cold winters and short, generally cool summers. Permanently frozen ground (permafrost), low precipitation, and persistent winds are important features of some, but not all, tundra environments.

Many people associate the term "tundra" with flat, featureless landscapes. But flatness is not a characteristic of tundra. Tundra occurs on flat plains, on rolling hills, and on precipitous mountain slopes just as do forests, deserts, and prairies. Additionally, many of the tundra areas that appear flat at first glance have surprisingly textured surfaces.

WHERE DOES TUNDRA OCCUR?
Periodic cold temperatures, and thus tundra environments, occur at high latitudes (near the north and south poles of the earth) and at high elevations throughout the world. Most of the tundra on earth occurs in the northern hemisphere because at high southern latitudes, the earth's surface is mainly covered by ocean.

WHY ARE THESE REGIONS COLD?
High Latitudes. Sites near the poles of the earth are cold because they receive less light and heat energy from the sun than do other areas of the earth. This occurs for two reasons. First, the earth tilts 23 1/2° on its axis, and so, in its annual rotation around the sun, each pole alternately tilts toward and away from this primary source of heat and light energy. Lands at northern and southern latitudes have days and nights of unequal length during most of the year. In June, the north pole is tilted toward the sun, so our days are long and nights are short. In December, the north pole is tilted away from the sun, so our nights are long, and days are short. Lands above the arctic and antarctic circles receive no sunlight during 2 months of winter, and little during the entire 6 months when the north pole is tilted away from the sun. In contrast, sites nearer the equator receive constant amounts of sunlight year round (day and night are of equal lengths).

Secondly, at high latitudes, even during the sunlit portion of the year, the sun is low on the horizon rather than overhead. The sunlight that reaches the earth's surface travels through more atmosphere and is spread over a larger area than at more southern latitudes. It therefore delivers less heat and light per unit area per hour.

At high latitudes, winters are long and cold, and summers are cool because of the seasonal tilt away from the sun of each pole, in combination with the low angle of the sun above the horizon during sunlit seasons. At Barrow, Alaska average daily temperatures drop below freezing in September, and remain so until May. From December through March, the temperatures ranges from -20° F (-28° C) to -16° F (-26° C) . At this high latitude site, the sun drops completely below the horizon on 18 November and does not rise again until 24 January.

High Elevations: Cold temperatures occur at high elevations for a different reason. At high elevations, the atmosphere is thin and contains little moisture, so little sunlight is reflected by particles in the air, and much more light and heat energy reach the ground than at low elevations. At first glance, then, it may seem surprising that cold temperatures, and thus tundra environments, occur at high elevations at all latitudes--even at the equator. The reason for this is that carbon dioxide and water vapor in the atmosphere act like a

blanket of insulation around the earth--by reflecting back, or trapping, heat energy. At low elevations, a thick, dense blanket of moist air traps much of the heat that reaches the ground. But at high elevations, the thin air over the mountaintops traps little heat, and provides little insulation fromthe -50°F (-45.5°C) temperature of the upper atmosphere. High elevation sites may have warm temperatures during the day when the sun is shining, but most of the heat is quickly lost when the sun goes down at night. On high mountains, night-time air temperatures are often 54° F (30°C) colder than those at mid-day. Average air temperatures drop 3° F (-1.7°C) for every 1000 feet (305 m) increase in elevation. Thus, when the air temperature is 32° F (0°C) at the base of Mt. McKinley, the temperature on top (20,000 feet) is 60° F colder, or -28° F (-34°C).

WHY IS THE TERM "PERIODIC" IMPORTANT: If the severe cold of northern winters and alpine nights was continuous, living things could not survive. The change from cold, nearly unlivable conditions to cool, milder ones more suitable for living things is thus an important characteristic of tundra environments. The periodic change from severe cold to milder conditions occurs seasonally (winter to summer) in most tundra environments. As one moves closer to the poles of earth, the mild season becomes shorter, and so does the number of kinds of living things that can survive. In high elevation tundra environments near the equator there is no seasonal change in temperatures, but warm (even hot) temperatures occur every day, while bitter cold occurs each night. Thus the term "periodic cold" applies to these environments, too.

PERSISTENT WINDS: Persistent winds are a feature of some, but not all tundra environments. They occur in coastal polar regions and at high elevations for basically the same reasons. Winds are the movement of air masses from one one place to another. They are caused mainly by differences in air temperature from place to place, and by the rotation of the earth. Cold air tends to sink, while warm air rises. When an air mass moves, other air must flow in to replace it. The temperature of a given air mass is determined by many factors, including the intensity of solar radiation, the varying reflectivities and temperatures of the surface over which the air passes, and the watervapor content of the air. Winds at high elevations are caused in part by differences in the air temperatures on mountaintops and in valleys. Because air masses can pile up on one side of a mountain, and large differences in air temperature can occur between high and low elevations, winds in mountainous areas are more severe and persistent than anywhere else. As an example, winds of 45-65 mi per hr (74-105 km / hr) with gusts of up to 100 mi per hr (161 km/hr) are common on Mt. McKinley, even in summer. Winds in coastal polar regions are caused in part by variations in the temperature of air masses over ice, water, and land, along with the rotation of the earth.

Even in tundra areas where the occurrence and strength of winds are similar to those of mild environments, the cooling and drying effects of wind are intensified because of the absence of trees to block it.

LOW PRECIPITATION: Tundra regions have been called "cold deserts." However, the amount of precipitation that occurs in tundra areas varies greatly. Tundra in the far north receives less precipitation than some deserts [less than 2 in (5 cm)] and thus deserves the name. But some tundra regions of southwestern Alaska receive over 40 in (102 cm) per year, and some alpine tundra areas of Alaska receive 80 in (2 m) of precipitation each year!

PERMAFROST: Permafrost, or perennially frozen ground, underlies all tundra areas (except large lakes and rivers) in the far north. In western and southwestern Alaska, and in Alaskan mountains, it is discontinuous (patchy). In the Aleutian Islands, and on mountaintops at more southern latitudes, permafrost is absent, or rare. However, seasonal and/or nocturnal frost occur in all tundra soils.

Permafrost, when present, and seasonal frost both play an important part in shaping tundra lands and ecosystems. Some surprising topographic features of tundra are created by permafrost and frost action. See the Tundra Wildlife Cards section of this packet for photos and descriptions of these features.

WHY DON'T TREES GROW IN TUNDRA?

Cold temperatures, short growing seasons, low sunlight intensity, high winds, abrasion, permafrost, cold soil, and lack of moisture combine to prevent tree growth in tundra.

COLD TEMPERATURES: Cold temperatures present a problem because energy, usually in the form of heat, is necessary for the chemical reactions of life to occur. Anyone who has ever been cold knows intuitively that warm-blooded animals (birds and mammals) must stay warm in order to survive. Plants, fungi, and even microscopic living things also have minimum temperatures below which they cannot function. All metabolic processes occur in water solutions, so many living things have difficulty functioning at temperatures below the freezing point of water. Many important chemical reactions occur more quickly at warm temperatures than at cold temperatures. Plants cannot photosynthesize (make sugar from light energy, water, and carbon dioxide) at temperatures below 19.4° F (-7° C) and other metabolic processes (such as respiration) do not occur at temperatures much below this. But air temperatures in some tundra environments average less than this for most of the year. At Barrow, for example, the average temperature is less than 0° F (18° C) from October through May. In alpine tundra environments, air temperatures can drop below freezing every night of summer as well. Thus, living things that generate little heat themselves--plants, fungi, insects, other invertebrates, and microscopic organisms, simply cannot function most of the time in tundra environments. In general, trees do not occur where July temperatures average below 50° F (10° C).

SHORT GROWING SEASON AND LOW LIGHT INTENSITY: The length of time (summer) when activity and growth of plants and many other living things is possible is very short in tundra environments. Thus, tundra organisms must gather enough energy and minerals to meet their needs for an entire year during just a few months. (At high latitudes, low light intensity further reduces the amount of energy that plants can collect during the growing season.) Large plants, such as trees, may be unable to survive in tundra environments in part because they are unable to store enough energy and minerals during the short summer, to meet their needs in spring and fall.

WIND: Persistent winds make life in tundra even more difficult. Living things must generate more heat or have better insulation to stay warm in a cold, windy environment than in an environment with cold, still air. This is because moving air carries heat away from the surfaces over which it passes. The faster the movement of air (the stronger the wind), the faster it carries heat away. The cooling power of air at 10° F (-12.2° C) with a 30 mph wind is the same as still air at a temperature of -33° F (-36.1° C). Persistent winds thus severely reduce the length of time that tundra environments are effectively warm enough for living things to function.

Wind also speeds the evaporation of water and can dry, or dessicate, leaves, and other living tissues. In dry environments, (such as some tundra) the drying effect of wind can be more harmful than its cooling effect. The living cells and tissues of most plants and animals will die if dried.

Alaska Wildlife Week 1988. Unit 6. Alaska's Tundra. © 1987 ADF&G

Wind also carries particles of dust, ice, and snow which cut and wear down any objects over which they pass. The living tissues of most plants, fungi, and other living things are easily damaged by constant scouring by these wind-blown materials. Every winter, anything that sticks up above the snow is soon cut, worn, and killed by the abrasion of ice crystals on the windward side. The abrasive power of wind borne ice crystals is another reason that trees do not survive in tundra environments.

PERMAFROST: Permafrost also contributes to the unsuitability of tundra for trees. Permafrost prevents tree roots from penetrating deep into the soil. Without a strong anchorage, any that grow up into the wind will be ripped out of the ground. Additionally, tundra soils are very cold, particularly in areas underlain by permafrost. This slows root growth, and reduces the ability of roots to take up water and minerals from the soil.

Since water can not penetrate it, permafrost also traps moisture in surface soils. Poorly drained permafrost ground soon becomes saturated with water, even in areas with desert-like precipitation levels. Most trees can not grow in water-saturated soils.

TREELESS TUNDRA IN A MILD CLIMATE:

The climates found at low elevations in coastal southwestern Alaska, the Aleutian Islands, and on Kodiak Island are not nearly as severe as those found on top of mountains and in arctic Alaska. In these regions, winter temperatures seldom drop below 10° F (-12° C), and the summer growing season is 1-2 months longer. While the wind seems persistant without trees to block it, it actually does not blow anymore in these areas than in other parts of coastal Alaska where trees do grow. So why are there no trees in the aforementioned areas? Scientists are still debating about the reasons. One popular idea is that trees have just not reached these areas. Most of these areas were covered by ice, separated from other land by ice or water, or had much colder climates up until about 10,000 years ago. When the glaciers retreated, trees returned to the newly exposed land slowly--encroaching from areas where some had survived the last Ice Age, (such as interior Alaska and parts of the Pacific coast). According to this hypothesis, trees have just not yet reached the expanses of suitable land in southwestern Alaska, or in the Aleutians, but could become established there in the future. The westward spread of tree seeds into coastal areas may be hampered by the strong winds that blow from the coast toward the inland forests. Some scientists argue that the treeless ecosystems on the Aleutian Islands do not fit the criteria for tundra, and instead should be called grasslands, or meadows.

Introductory Activity 1.

Objective:

Students will be able to explain how cold environments are distributed on the earth and the reasons for their distribution.

Skills:

SCIENCE: measuring, inferring, predicting, synthesizing
LANGUAGE ARTS: reading, writing

Materials:

You will need a world almanac, an atlas showing world environments, and the materials to set up the 4 stations described on the following pages, including: copies of the student instructions and: Station 1: a moveable lamp (without a lampshade), a globe (or a styrofoam ball with a pencil stuck through the center and the continents drawn on its surface); Station 2: an incandescent lamp or direct, bright sunlight, modeling clay, 2 lids from a metal can, both painted black, 1 or 2 thermometers; a flashlight, a piece of cardboard, a ball or globe; Station 3: 3 jar lids, tape, 3 small thermometers, string, 2 jars--1 small, the other very large; Station 4: an electric fan, 2 thermometers, 2 identical jars, warm water, pan of ice.

Procedure:

SUMMARY: Students will make observations and measurements at each of 4 stations and use their findings to predict the distribution of cold environments on the earth.

1. PREPARATION: Set up the 4 Stations as described in the instructions on the following pages. Post the instructions at each station. Divide the class into small groups.

2. STUDENTS CONDUCT THE EXPERIMENTS: You may have all groups of students do all 4 experiments, or have separate groups do separate experiments and then report their findings to the class.

3. DISCUSS THE EXPERIMENT RESULTS: The last 1 or 2 questions on each of the student instructions require students to apply their findings to make predictions about the distribution of solar energy, or the rate of heat loss from different parts of the earths surface. Discuss each of these questions to ensure that students understood the questions and arrived at reasonable predictions.

4. STUDENTS TEST THEIR PREDICTIONS: Ask students whether there is any way they could test their predictions. (They may initially think that they need to go to various places on the earth and test the intensity of solar radiation, or the rate of heat loss.) Encourage them to think how the amount of solar energy and rate of heat loss of a particular site would affect its climate. Can students infer that the places on the earth that receive the least solar energy and which lose heat most quickly will have the coldest climates? Based on their experimental findings, what regions of earth should have the coldest environments? (Areas near the poles and mountaintops.) Have students use an almanac to determine the climate at various latitudes and elevations on earth. Were student predictions correct?

5. REVIEW STUDENT UNDERSTANDING OF THE CONCEPTS: Ask students to reiterate why environments at high latitudes are cold, and why environments at high elevations are cold. (Can they adequately explain why?) Then, ask them, considering the different reasons for the cold environments in these areas, how would these two kinds of cold environments differ? Or would they be the same? (Based on their experiments, they may be able to recognize that high latitude environments will have long, annual periods of darkness, while high elevation sites at lower latitudes will not. They may also recognize that day / night temperatures will vary more at high elevations than at low elevations.)

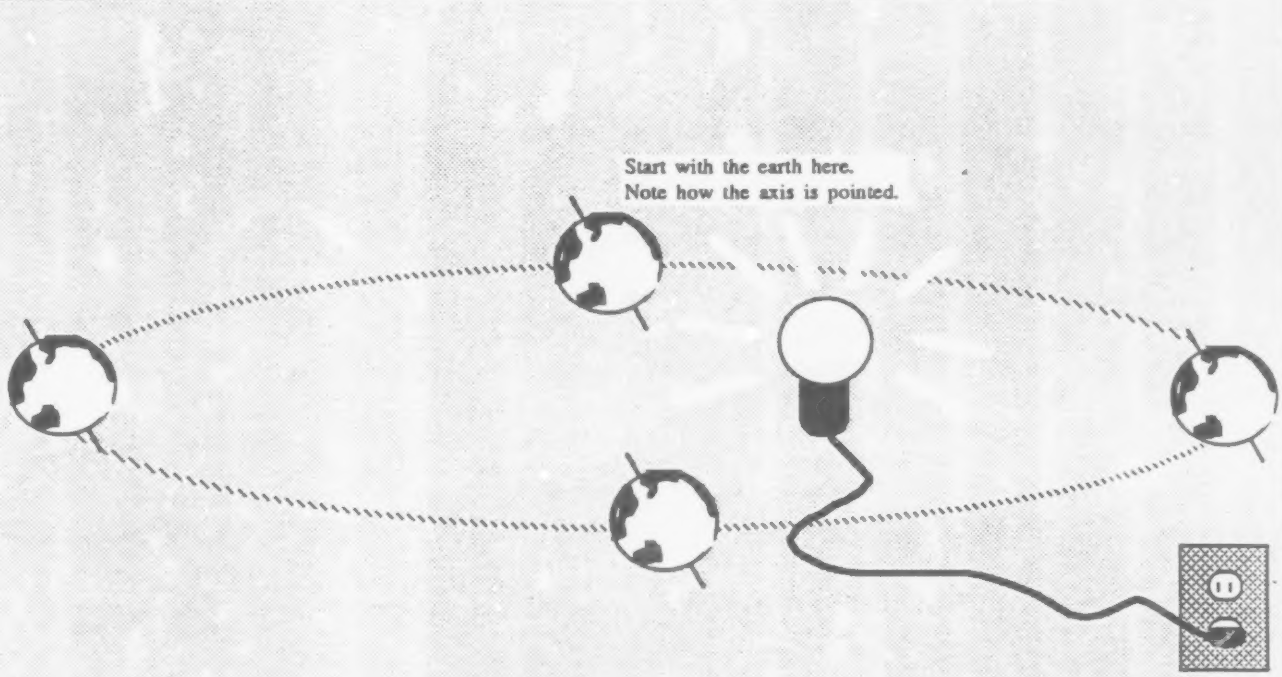
6. STUDENTS LOOK AT PHOTOS OR ILLUSTRATIONS OF TUNDRA ENVIRONMENTS: Explain that tundra is a word used to describe most of the environments found in the parts of the earth with cold climates. Tundra at high northern latitudes is called arctic, or lowland tundra, while tundra at high elevations is called alpine tundra. Have students look at an atlas showing photos of lowland and alpine environments throughout the world.

Evaluation:

Have students complete Worksheet 1a and 1b.

Alaska Wildlife Week Unit 6. © 1988 Alaska Dept. Fish and Game

TEACHER PREPARATION: Use a globe, or sketch the major continents on a styrofoam ball along with the equator and 66°33'N and S latitudes (the arctic and antarctic circles). Insert a pencil or wire through the center of the styrofoam ball. Set the light up on a small table so that students can walk around it.



STATION 1. Student Instructions:

1. Use this globe and light to figure out how and why the amount of solar energy reaching the earth varies. Use the light to represent the sun (turn it on), and the globe (or styrofoam ball) to represent the earth. Note the the location of the north and south poles on your model earth. Find Alaska on your model of earth. The earth tilts on its axis (23 1/2°) as shown in the diagram above. Hold the globe up so that its axis is tilted as shown in the diagram, and place it in the start position shown in the diagram. As you probably know, the earth rotates, or spins, around its axis, once every 24 hours. Spin your model earth and watch the how the amount of light, or solar energy, received by the earth's continents changes as the earth rotates. (The places on the globe that are lit are receiving solar energy, the places in shadow are not.)

a. Based on your observations, explain why each spot on earth receives solar energy for only 12 hours each day. What do we call the period of the day when the location we are at is receiving solar energy?

2. The earth not only rotates on its axis, it also revolves, or circles around the sun in an elliptical orbit--that means its path is a compressed circle. It takes 365 days, or 1 year, to travel this big ellipse. Use your model to observe how the amount of solar energy reaching Alaska changes as the earth revolves. Keep the axis of your model earth pointed in the same direction (the earth does not tilt back and forth on its axis--it always tilts the same way), and move your "earth" around the "sun." Based on your observations answer the following questions:

a. Does the amount of solar energy received by Alaska change as the earth revolves around the sun? Why? Does the amount of solar energy received by Antarctica change as the earth revolves around the sun? Why?

b. Does the amount of solar energy received by sites at the equator change? Why?

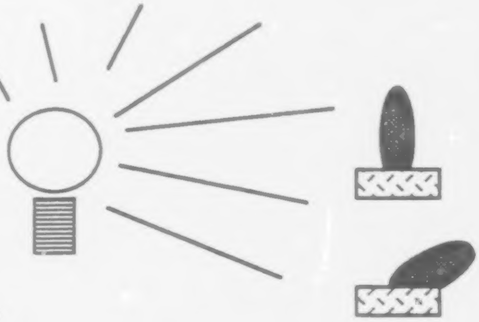
c. What regions of the earth receive the same amount of solar energy throughout the year? What regions receive solar energy for only part of each year? What regions receive the lowest amount of solar energy?

d. When northern regions are receiving lots of solar energy, what is happening near the south pole?

e. Try rotating your model of the earth at different spots in its revolution around the "sun". Does Alaska receive solar energy for a longer period of time during any part of the earth's revolution? What season of the year do you think this is? Why is Alaska's winter sometimes called the "arctic night"?

Station 2. Teacher Preparation

Place 2 lumps of clay, 2 lids of metal cans that have been painted black, a bright, incandescent light (or direct, bright sunlight), 2 thermometers, a penlight, a piece of cardboard, and a globe or ball, along with the student instructions at this station.



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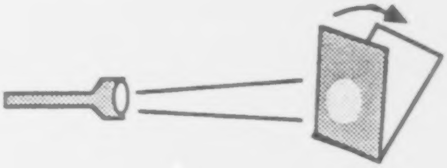

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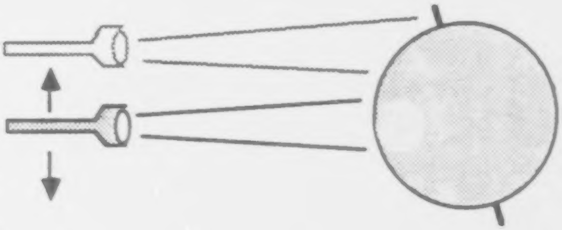


3.

Station 2. Student Instructions

Sunlight is made up of heat and light energy. When it strikes molecules in the air or on a solid surface, its energy is either reflected or absorbed as heat. Each ray of sunlight contains the same amount of heat and light energy. Try the following experiments to find out how the angle of incidence--that is the angle at which sunlight strikes an object--affects the amount of heat and light energy received.

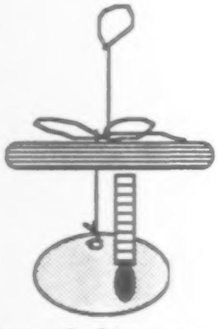
1. Stand 2 tin can lids, painted black, at different angles, using modeling clay as a base. See the diagram for an example. Place these an equal distance away from an incandescent light bulb (but within a short enough distance that you can feel the heat of the light bulb on your hand), or in direct, bright sunlight. Wait 15 minutes (go on to the next step while waiting), then measure the temperature on the surface of each lid. You may be able to feel the difference with your fingers. Which one got warmer? Which one received the most light and heat energy?

2. While you are waiting for the results of the above experiment, shine a penlight against a piece of cardboard. Keep the light close enough that you can see a distinct circle of light. First hold the cardboard straight up and down, and note the size of the circle of light. Then, slowly tilt the cardboard either toward or away from the light. What happens to the circle of light? Considering that the amount of light generated by the flashlight has remained the same, how do you think the amount of light energy received per unit area changes as the tilt of the cardboard, that is the angle at which the light strikes the surface, increases? Based on this experiment, can you predict what kind of difference you will find when you measure the temperature of the lids in Step 1.

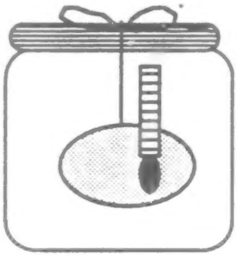
3. Imagine that the penlight represents the sun. Keeping in mind that the earth tilts on its axis, shine the penlight on the globe or ball (representing the earth). Hold the light so that the beam of light is perpendicular to the equator. Hold the light close enough to the globe that you can see a small, distinct circle of light. Compare the size of the circle that appears when the light is shown on the equator to the size of the circle when the light is shown at the poles. (Be sure to hold the light beam perpendicular to the equator in both cases.) Based on your observations, what regions of earth receive the most solar energy per unit area--i.e. the highest intensity of solar energy? Which receive the lowest?

Station 3. Teacher Preparation

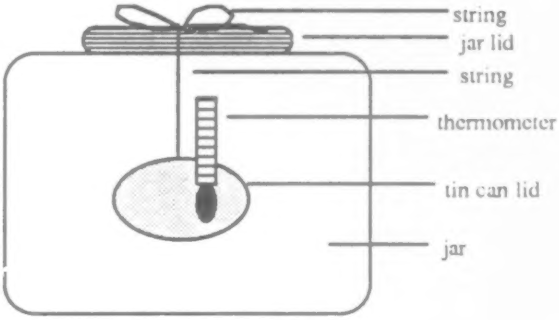
Collect the following materials: 1 large and 1 small glass jar with large mouths and lids, 1 extra jar lid, string, 3 small thermometers, tape, 3 tops from tin cans. Put the materials together as shown in the diagram and place these along with the student instructions at Station 4.



Prepare 3 of the above. Suspend a tin can lid from a jar lid with string. Tape a small thermometer to the metal.



Place one inside a small jar. Close the lid tightly.



Place one inside a large jar. Close the lid tightly.

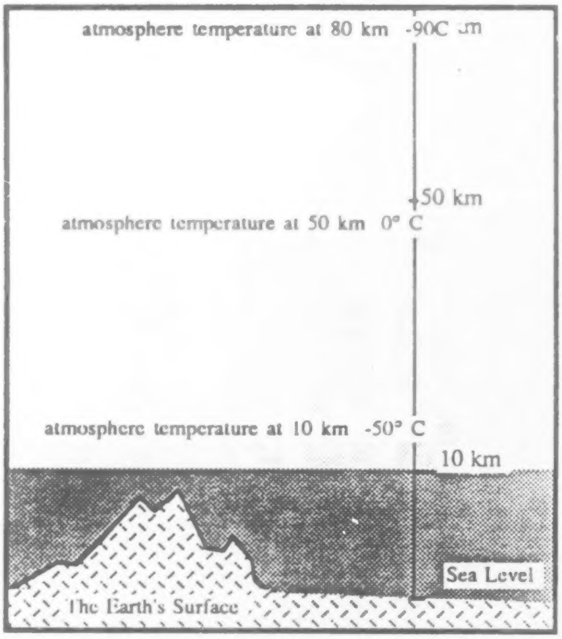
Station 3. Student Instructions

Imagine having a coat made out of air. Could it keep you warm? You can do an experiment to find out whether air can help keep something warm.

1. Set up the jars as shown in the diagram above. Record the temperatures of the metal inside each jar. Then, place all the thermometers outside in direct sunlight (or under a bright, warm light). Check the thermometers every 10 minutes. How did the temperatures in the jars change? Which temperature changed the most? Why?

2. After completing step 1, equalize the temperature of the three metal lids, then place all of them as shown above, outside in the shade. Wait at least 15 minutes. How did the temperatures change this time? How do you explain this?

3. The earth is surrounded by a layer of air, called the atmosphere. The diagram below shows the way the earth's atmosphere covers the earth's surface. The air and the glass jars showed the way that the earth's atmosphere affects heat gain from sunlight and heat loss to space. Based on the results of your experiment, and the information in the diagram, explain why the air is colder on mountaintops than at low elevations. Why is the atmosphere like a blanket?


atmosphere temperature at 80 km -90C
50 km
atmosphere temperature at 50 km 0° C
atmosphere temperature at 10 km -50° C
10 km
Sea Level
The Earth's Surface

The earth's atmosphere is made up of molecules. Over 75% of the molecules in the atmosphere are in the lower 10 km of air. The temperature of the atmosphere is -50° C at an altitude of 10 km. Only a thin layer of air separates mountain peaks from this severe cold. (The atmosphere warms to about 0° C at 50 km due to a layer of ozone molecules at this altitude which trap sunlight energy as heat.)

Alaska Wildlife Week Unit 6. © 1988 Alaska Dept. Fish and Game

Station 4. Teacher Preparation

Place an electric fan, a pan of ice, 2 empty metal cans, 2 thermometers, and a pail of water along with the student instructions at this station.

Station 4. Student Instructions

Do you think wind affects the temperature of the environment? This experiment will help you find out whether your ideas are correct.

1. Measure the air temperature about 2 feet in front of the electric fan, but with the fan turned off. Record this temperature.

2. Turn the fan on high and measure the air temperature again. Be sure to wait a few minutes to allow the thermometer to respond to any change. Was there one? Now, do you think the wind affects the temperature of the environment?

3. Try another experiment. Fill up the two cans with warm water and place a thermometer in each one. Record the starting temperature of each. (This is important because even if the water temperature in the two containers is the same, the two thermometers may register slightly different.) Place one can of water aside, away from the fan, and the other one in front of the fan. Wait about 15 minutes, then record the temperature of the water in both containers again. Did the temperature in both containers drop the same number of degrees? Which one dropped further? The drop in temperature is a measure of heat loss. After this experiment, how do you think wind affects the temperature of the environment?

4. Try one more experiment. Repeat the step above, except this time, place a pan of ice between the fan and the can in front of it. Wait 15 minutes. Did the temperature in this can drop more, less, or the same amount as in the last experiment? Did it drop more, less, or the same amount as the temperature of the other can? Explain why. What do you predict would occur if you placed a heated surface between the fan and the can?

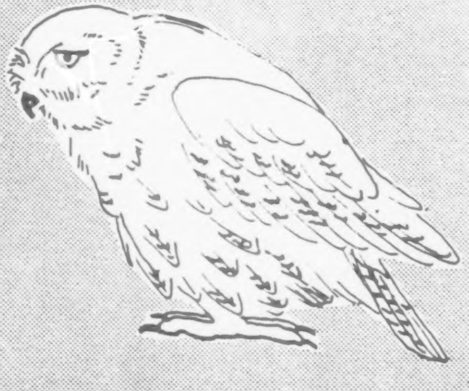
5. Based on what you observed in these experiments, choose which environment from each of the following pairs where a living thing would have the most difficulty keeping warm?

a. a coastal environment adjacent to pack ice with winds blowing toward the shore
a coastal environment near pack ice with winds blowing toward the sea

b. a cold, calm environment
a cold, windy environment

TUNDRA AROUND THE WORLD SOCIAL STUDIES, SCIENCE.......... ....INDOORS

OBJECTIVES: Students will become familiar with the distribution of tundra environments around the world.
SKILLS- geography, use of an atlas, maps, and encyclopedias
MATERIALS: Copies of a blank map of the earth's continents or an enlargement of one on to butcher paper, an atlas, encyclopedias
PROCEDURE:
1. STUDENTS IDENTIFY THE MAJOR GEOGRAPHIC FEATURES OF THE EARTH. Ask students to draw in and label the following on their map: the equator, latitudes in 10 degree intervals, names of all continents, the 3 largest rivers on each continent, and the mountain ranges on each continent.
2. STUDENTS MAP THE BIOMES OF EARTH: Have students look at vegetation maps for each continent or country, and color in the kinds of environments on each continent, using different colors to show tundra, forest, desert, and prairie.
3. DISCUSS THE DISTRIBUTION OF TUNDRA ON EARTH. Have students use their maps along with a map showing political boundries to make a list of countries in the world that contain tundra, and determine which countries and places have the most. Ask students to figure out why there is more tundra in the northern hemisphere than in the southern. Can they figure out that there is little land at high southern latitudes where the environment is cold enough to cause tundra?



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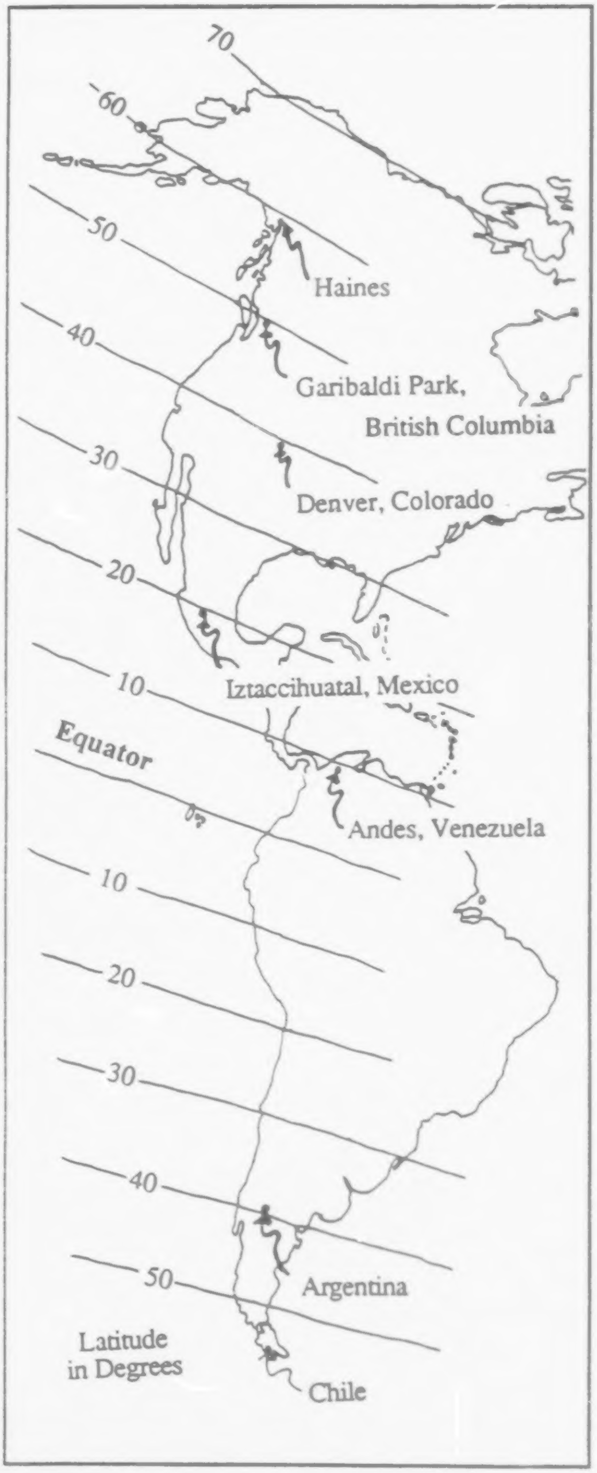
TUNDRA PICTIONARY....... ......LANGUAGE ARTS / ART

OBJECTIVES: Students will recognize the topographic features of permafrost soils and become familiar with the terms used to describe them, along with other vocabulary words.
SKILLS: vocabulary building, teamwork
MATERIALS: copies of the pages describing the topographic features of tundra (pages 11-14), the tundra glossary, vocabulary words and names of tundra topographic features written on index cards, blackboard and chalk, or pencil and paper
PRODEDURE:
1. STUDENTS REVIEW THE TUNDRA FEATURES: Allow students 15 -20 minutes to study the descriptions of tundra topography, and the glossary. (Or, assign these as reading homework.)
2. STUDENTS PLAY PICTIONARY: Divide the class into groups of 3-5 students. Each group should have an area of blackboard and chalk, or paper and pencils. Tell students that you will show one player on each team a "tundra word." That player will draw, while the remaining players try to figure out what word the drawer is attempting to communicate in their drawing. The person who draws may draw a picture of the object the word describes, or any pictures that might help their teamates guess the word. All teams will play at once with the same word (one player drawing and the others guessing). The first team to guess the word wins 1 point and the chance to give its definition. If they can define it they earn 2 more points. If not, the first team to raise their hands gets a chance to earn 2 points by correctly defining the word. (They lose 1 point if they define it incorrectly.) If neither team correctly defines it, read the definition and discuss it, then retain that card for re-use.

Once a word has been guessed correctly and defined, each team selects a new artist. Show the new artist of each team the next "tundra word" and play round 2. Continue as long as possible, or until all of the glossary words have been correctly defined.

Alaska Wildlife Week Unit 6. © 1988 Alaska Dept. Fish and Game

Worksheet 1a.
Changes in Latitude


70
60
50
40
30
20
10
Equator
10
20
30
40
50
Haines
Garibaldi Park,
British Columbia
Denver, Colorado
Iztaccihuatal, Mexico
Andes, Venezuela
Argentina
Chile
Latitude
in Degrees

Name______________________________

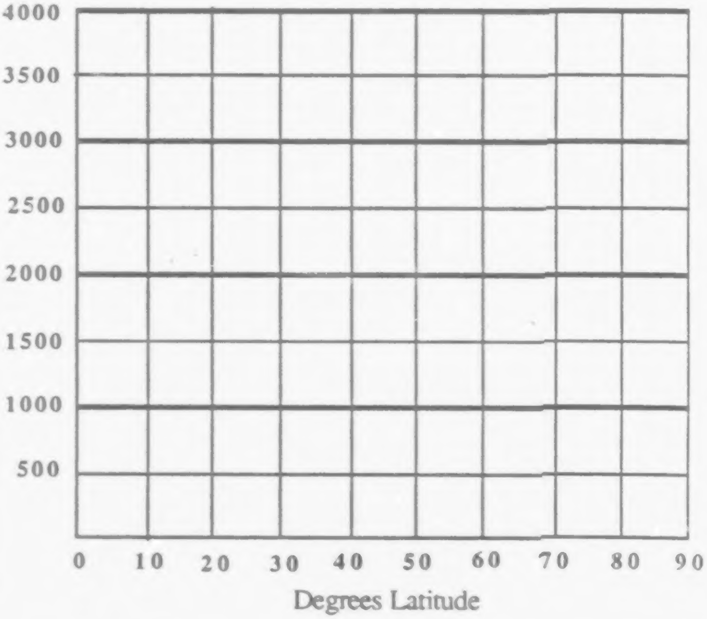
Treeline is the environmental boundry between forest and tundra. A treeline occurs at the southern edge of lowland tundra. Other treelines occur on mountaintops around the world, at the lower edge of alpine tundra. Use the following data and the map above to make a graph comparing latitude and the elevation at which treeline occurs on mountain slopes.

Location	**Treeline Elevation in Feet**
Denver, Colorado	3350
Haines, Alaska	900
Iztaccihuatal, Mexico	3950
Garibaldi Park, British Columbia	2150
Andes, Venezuela	4200
Andina de Neuguen, Argentina	1650
Southern Chile	4900

Based on your graph, use the following words to describe how latitude and the elevation of treeline are related:

increases decreases higher
lower increase decrease

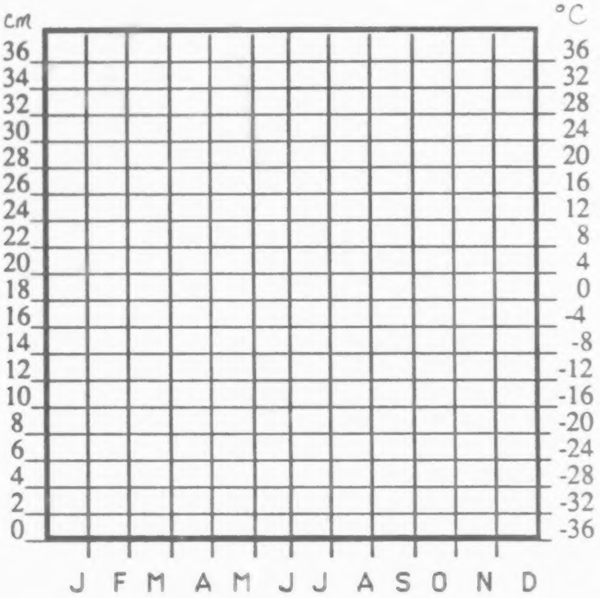
1. As the latitude ____________, the elevation at which treeline occurs ______________.
2. In other words, alpine tundra occurs at _________ elevations at high latitudes.
3. A 10 degree increase in latitude results in an approximate ______ feet ____________ in the elevation of treeline.
4. Locate your town on the map, and figure out the elevation of treeline near you. Record it here: ____________
5. At what latitude do you think *lowland* tundra begins? _________



Worksheet 1b. Biome Climates

Name______________________________________

Contact your local weather service, or use a library reference to find out the average monthly temperature and precipitation. If necessary, convert the temperatures into degrees Celsius, and the precipitation measurements into centimeters. (° F -32 x 9/7 = ° C; 1 inch = 2.54 cm) Record these and make a bar graph of the precipitation, and a line graph of the temperature on the chart below.



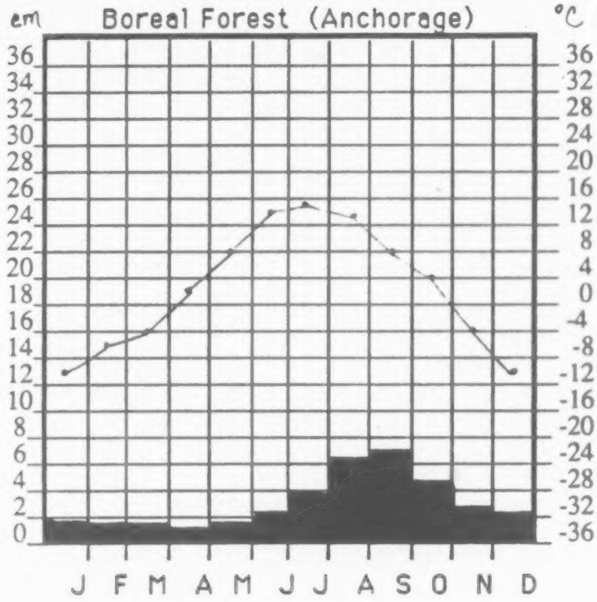
Location A.	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Temperature	-26	-28	-26	-18	-7	1	4	3	-1	-9	-18	-24
Precipitation	0.6	0.5	0.5	0.5	0.5	0.8	2.0	2.5	1.5	1.3	0.8	0.5
Wind	23	18	16	21	21	19	21	19	21	16	21	18

Location B.	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Temperature	-20	-20	-18	-11	-1	6	12	10	5	-4	-13	-20
Precipitation	0.6	0.8	0.8	0.8	1.0	1.3	3.8	5.1	3.8	1.5	1.0	0.8
Wind	26	21	14	19	14	21	19	21	21	21	34	29

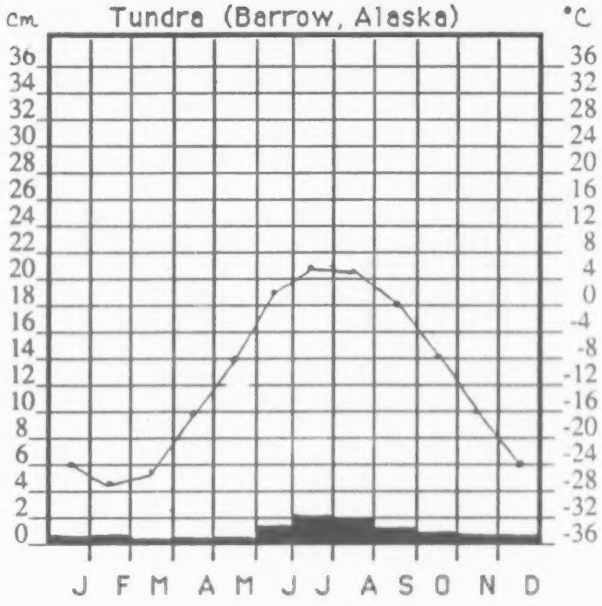
Location C.	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Temperature	-15	-13	-12	-4	4	11	13	11	7	-1	-8	-16
Precipitation	1.3	1.9	2.0	1.3	2.0	3.2	5.1	10.2	6.1	3.3	2.5	1.3
Wind	21	26	23	21	18	26	21	19	23	19	26	26

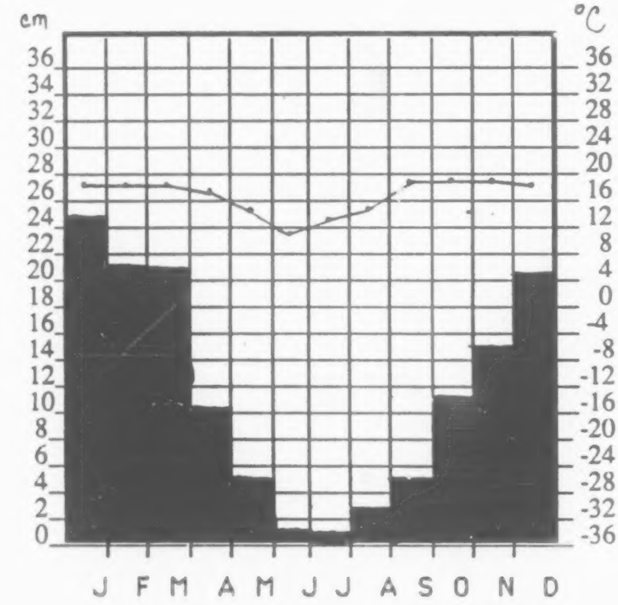
Location D.	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Temperature	-2	-2	-2	1	4	7	10	11	8	4	-4	-2
Precipitation	7.6	7.6	5.1	3.8	5.7	4.6	5.6	9.9	9.9	11.4	10.2	6.4
Wind	24	27	26	24	24	27	29	29	26	24	31	31

Boreal Forest (Anchorage)

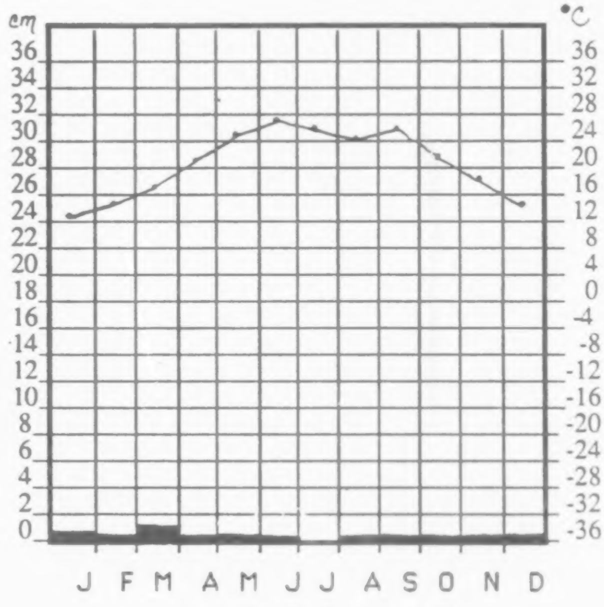


Tundra (Barrow, Alaska)





Tropical Forest (Cuiba, Brazil)

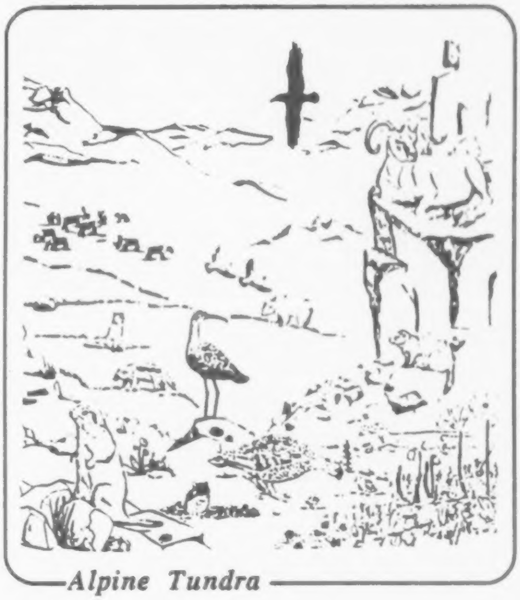


Desert (Aden, Aden)

The climatographs above show the average temperature in degrees Celsius and the amount of precipitation in centimeters for 4 different biomes: tundra, boreal forest, desert, and tropical forest.
Which two environments are the driest?
Which are the wettest? Which are the two coldest?
Which are the two warmest? Which environment does not have a hot and cold season?
Make climatographs for each of the locations described on page 1, then predict the type of biome found at each of them. (In general, trees can not survive in environments without at least one month of temperatures averaging above 50° F. Permafrost is most common in areas with a mean annual temperature below -4° C.) Compare the climatograph you drew for your home area to the other climatographs. To which of the climatographs that you drew is it most similar? How is it different? How do you predict that your local environment differs from the one to which it is most similar? After you have made your predictions, ask your instructor for a list of the names of the locations from which the climate information on page 1 was gathered. Locate each of these on a map. Were your predictions about the environment in each location correct? Why do you think scientists debate about the name that should be applied to the tundra of southwestern Alaska?

The idea for this activity and some of the climate information is from University of Colorado, Biological Sciences Curriculum Study, Green Version, High School Biology, Rand McNally and Company, Chicago, 1968.

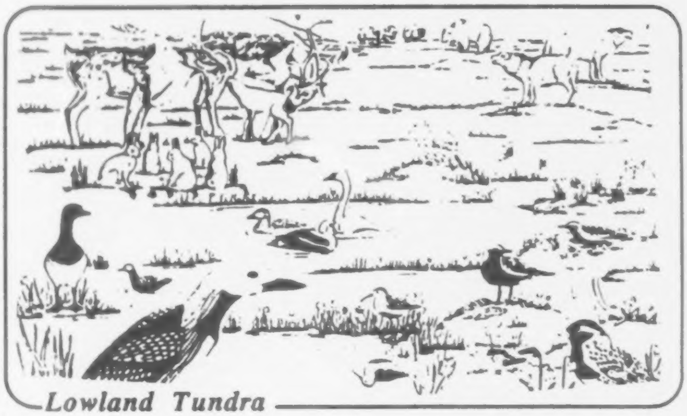
Lesson 2.



Alpine Tundra

Vocabulary

alpine tundra, animals, fungi, lowland tundra, monerans, permafrost, plants, protists, solifluction, wetland



Lowland Tundra

Objectives:

Students will be able to differentiate alpine and lowland tundra ecosystems, describe the characteristics and distribution of each in Alaska, and become aware of the variety and abundance of living things that occur in each tundra type.

Teacher Background

IS ALL TUNDRA THE SAME?
Nearly half of the land in Alaska is tundra, but not all tundra is alike. The term "tundra" is used to describe all ecosystems that share the characteristics of periodic severe cold, short growing seasons, persistent winds, and the absence of trees. These characteristics make all tundra ecosystems look superficially similar, but the non-living environments and the species of living things present vary between regions and specific areas. The two main types of tundra ecosystems that occur in Alaska are alpine and lowland tundra, but even within these categories tundra ecosystems vary from one region to another.

HOW DO ALPINE AND LOWLAND TUNDRA ENVIRONMENTS DIFFER? [Descriptions of alpine and lowland tundra intended for reading by students are provided on pages 22-27.]

- Alpine tundra occurs at high elevations (mainly on mountains) throughout the world, while lowland tundra occurs at low elevations in polar regions, coastal subarctic areas, and on subantarctic islands. In Alaska, lowland tundra occurs north of the Brooks Range, in northwestern and western Alaska. (The treeless environment in parts of coastal southwestern Alaska and the Aleutian Islands is also sometimes classified as lowland tundra, but it is warmer and moister than typical lowland tundra, and is sometimes classified as grassland.) Alpine tundra occurs on mountains throughout the state; it grades into lowland tundra in northern and western Alaska.
- Alpine tundra is a discontinuous habitat. It occurs in patches separated by the forests and wetlands of lower elevations, and the ice and snow of high elevations. Many alpine sites are like islands of tundra. In contrast, lowland tundra covers vast, continuous expanses of land, such as the North Slope and the Yukon Kuskokwim River Delta.
- The topography of alpine and lowland tundra differs greatly. Alpine tundra sites are characterized by abrupt changes in slope and aspect; flat and gently sloping areas are intermixed with steep slopes and cliffs. The underlying terrain of lowland tundra, in contrast, is generally flat, or gently sloping. However, wind, water, and permafrost continually shape and carve the surface of lowland tundra. In lowland tundra areas underlain by permafrost, topographical relief occurs, including thermokarst ponds, ice wedge troughs, thaw lakes, high and low-center polygons, and pingos,

ice-filled hills that can rise 164 feet (50m) above their surroundings. (See the illustrations and descriptions of these features in the Tundra Wildlife Cards Supplement to this packet.)

- Daily temperature fluctuations are more extreme in alpine than in lowland tundra. The air at high elevations is less dense than the air at lower elevations. As a result, alpine tundra receives more intense solar radiation (less is filtered by the atmosphere) during the day, and cools more quickly at night. Freezing temperatures may occur at night year-round in alpine tundra. Long cold winters occur in both alpine and lowland tundra, but a 2-month period of darkness with little or no sunlight occurs only in tundra at high latitudes (mainly lowland).
- Most alpine areas receive more snowfall, and thus more precipitation, than lowland tundra. Alpine areas in northern Alaska receive about 20 inches (51 cm) of precipitation per year, but alpine tundra regions in southcoastal Alaska receive 100-200 inches (250-500 cm) or more. (In some southcoastal Alaska mountains, scientists have recorded as much as 18.75 feet (5.7 m) of snow in a single month!) In contrast, most lowland tundra receives only 4-20 inches (10-51 cm) of precipitation per year. This level of precipitation is comparable to that of deserts and arid grasslands.
- Contrarily, most alpine tundra is dry, while most lowland tundra is wet or moist. High winds, dry air, intense solar radiation, shallow soils, and good drainage due to the mountainous topography result in dry condtions in most alpine tundra, despite heavy snowfalls. However, some alpine sites have adequate or abundant water; snowbanks that melt slowly provide a continuous supply of water to sites below them, and water collects in depressions and flat areas of alpine tundra.

In striking contrast to the dry, rocky land of alpine tundra, most of Alaska's lowland tundra is wet or soggy during summer. This occurs because nearly all lowland tundra is flat or gently sloping, and is underlain by permafrost (perennially frozen soil). Water cannot seep through permafrost, and flows slowly over flat ground, so all of the water from rain and snowmelt remains on the surface in lowland tundra. Evaporation and transpiration (the release of water vapor into the air by plants) occur slowly due to the cool temperatures. Thus, many lowland tundra areas remain wet during the entire summer.

- Shallow soil, rock piles, rock outcroppings, and cliffs are important features of alpine tundra, though deep soil occurs in gently sloping areas. In contrast, most lowland tundra sites have deep soil and rock outcroppings are uncommon except in the high arctic.

The exposure of bare rocks in alpine areas results from soil erosion caused by landslides, avalanches, high winds, fast-running meltwater, solifluction (sliding of the active layer of soil atop the permafrost layer on sloping land), and frost-heaving.

Little erosion occurs on the relatively flat terrain of lowland tundra; most dead organic matter remains in place or is washed into lakes and ponds. Centuries of accumulation have resulted in deep layers of partially decayed material, or peat. Many lowland tundra areas are also periodically flooded by slow-moving rivers that deposit silt and organic material from upriver.

- Environmental conditions in alpine and lowland tundra vary considerably depending on latitude, elevation, aspect, and slope. Both types of tundra gradually change from very dry, cold environments with lots of bare soil and rocks, to zones where most of the ground is covered by lichens and mosses, and finally to a warmer, moister zone dominated by low shrubs. In alpine tundra, this variation occurs mainly over an altitudinal gradient, from high to lower elevations. Variation in lowland tundra occurs mainly along a latitudinal gradient from northern, arctic regions to more southern, coastal subarctic regions.

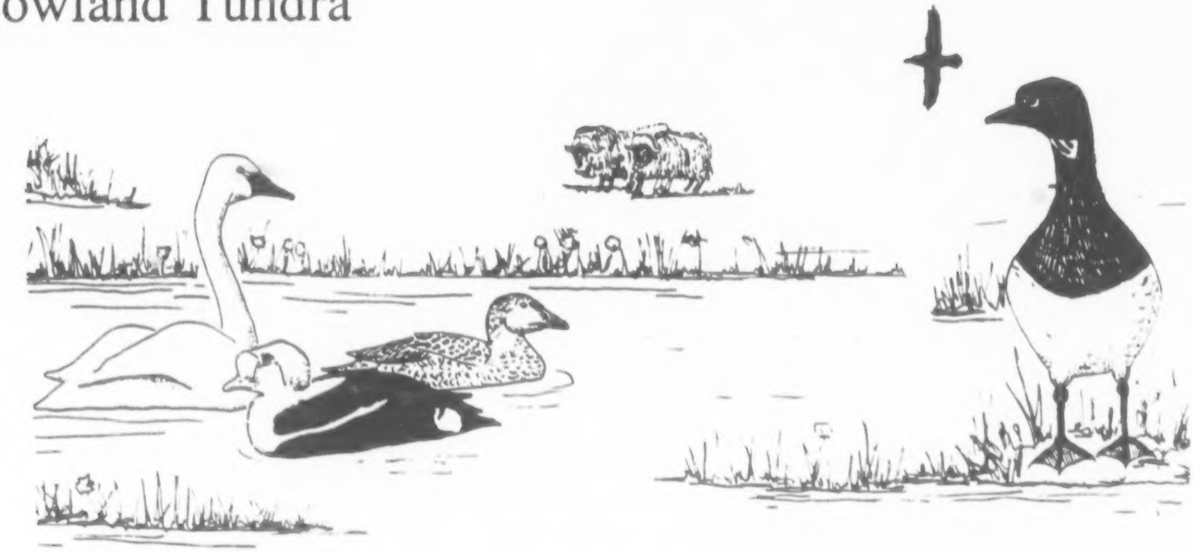
WHAT LIVING THINGS OCCUR IN ALASKA'S TUNDRA ENVIRONMENTS?

Considering the severe conditions of tundra environments, it seems surprising that any living things can survive in the tundra regions of the earth. In fact, some people mistakenly assume that tundra is barren and desolate wasteland. However, representatives of all five kingdoms of living things occur in tundra environments. Though generally fewer species occur than in milder environments, many of the species present occur in astonishing abundance. Many of the species of plants, animals, and other living things found in tundra do not live in other environments.

The numbers and variety of living things present decreases as the severity of the climate increases; thus fewer species of living things are found on the tundra in the far north than in the subarctic maritime tundra, and, in alpine tundra, more species are found near treeline than at higher elevations. Some kinds of living things occur in both alpine and lowland tundra. But, many alpine tundra wildlife require well-drained, dry, rocky, or precipitous sites that are not available in lowland tundra, while many wildlife of lowland tundra are aquatic or semi-aquatic and could not live in dry alpine tundra.

General information about the living things found in Alaska's tundra ecosystems is provided in the introduction to the Tundra Wildlife Cards that go with this packet. Also, see the three posters that accompany this packet for illustrations and photographs of many tundra wildlife.

Lowland Tundra



Lowland tundra has been described as barren wasteland because its seemingly flat expanses, cold temperatures, and howling winds impressed some visitors with a sense of desolation. But lowland tundra is a special environment. Its wealth is partly its vastness, its impressiveness is partly its harshness. Few other environments on earth vary as much, provide as great a challenge to life, or offer comparable displays of living wealth. Mere inches of elevation make the difference between desert and swamp. An animal bone can make the difference between bare ground and miniature jungle. A day can make the difference between seeing nothing, and seeing 100,000 caribou or 250,000 eiders.

This fascinating environment covers 98 million acres (89,000 sq km) of northern and western Alaska. It varies considerably throughout this large area, because the climate and day length vary widely from north to south. While daytime temperatures in the far north are often -30° F (-34° C) or colder (in winter), temperatures rarely drop below +32° F (0° C) in the Aleutian Islands. Annual precipitation varies similarly, from 4 inches (10 cm) or less in the extreme north, to 40 inches (102 cm) or more in southwestern Alaska. Considering this wide variation in climate, the similarity of lowland tundra throughout this huge area seems more striking than its variation. However, some major differences in topography and wildlife do occur.

The presence of continuous permafrost in northern and northwestern areas and its absence from southern areas is perhaps the most obvious difference caused by climate. Permafrost, or perenially frozen ground, lies a few inches to a few feet below the soil surface and can extend to depths of 2240 feet (700 m). The shallow layer of soil that lies on top of the permafrost, called the active layer, thaws and refreezes every year. Permafrost and the annual freezing and thawing of the active layer combine to create startling topographical patterns in northern lowland tundra. Anyone who attempts to walk across the lowland tundra of northen Alaska soon finds that its flatness is an illusion. The land surface is gouged by ravines, gullies, troughs, and sinks, and pockmarked by rises, hillocks, and mounds. hermokarsts, ice wedges, pingos, frost boils, and high and low center polygons are all landscape features created by permafrost (see diagram). These are found in lowland tundra of northern and western Alaska, but are absent from tundra of southwestern Alaska.

Bitter cold temperatures and raging winds envelope most lowland tundra for 7-8 months of every year. The tundra seems fairly lifeless during this season because nearly all living things become inactive, or migrate to milder environments during winter. However, a few mammals and birds remain active in parts of lowland tundra year-round. In the coldest tundra regions, muskoxen, arctic foxes, collared and brown lemmings, weasels, tundra hares, and snowy owls remain active. Willow and rock ptarmigan, ravens, redpolls, gyrfalcons, muskrats, beavers, voles, and even shrews also remain and are active throughout the winter.

Most of the winter's accumulation of snow melts within a 1-2 week period in late May or early June. Windblown dry sites are the first to show through the snow, and the first places where plants and insects awake from their winter dormancies. These patches of bare ground are used by snow buntings--among the first spring arrivals. As the bare patches expand, low spots in the tundra become flooded with meltwater.

The flood of water that covers most lowland tundra in spring is surprising, considering that most lowland tundra sites receive less precipitation than some deserts. This flood occurs because most precipitation in lowland tundra occurs during winter as snow, and all the spring meltwater has nowhere to go. Water can not flow into frozen ground, and flows over the the surface slowly due to the flat and gentle slopes of lowland tundra. Most of the water eventually collects on the low, flat spots of the tundra, such as in the center of low-center polygons, in ice wedge troughs, and in lakes, ponds, and rivers. Evaporation occurs slowly at low temperatures, so areas that are flooded in spring remain wet throughout most of the summer. Thus, much of the lowland tundra in Alaska is a wetland--an area covered by water during all or part of every year.

An explosion of life occurs as the tundra begins to flood with meltwater in spring. Flocks of migratory birds arrive hourly. Geese, cranes, shorebirds, and longspurs soon crowd the bare ground of tundra. Loons, phalaropes, eiders, and oldsquaw ducks soon begin disputes over ownership of still frozen ponds and lakes. Where days before the only sounds were the cracking of ice and howls of the wind, the tundra becomes alive with the songs, calls, and motion of these birds. Within a few days after arriving, most will have begun nesting.

Almost as soon as liquid water is available, many plants begin to grow, even beneath a cover of snow. They begin to push forth leaves and flower buds using energy stored in their roots. Shortly after snowmelt, the tundra is covered with green leaves and dotted with yellow and purple flowers.

In northern Alaska, caribou return to their tundra calving grounds just before the migratory birds. In some areas, tens of thousands of caribou are scattered around in small groups. Nearly all of the cows give birth to their young within about a one-week period. Other tundra animals are also busy raising young. Arctic foxes, muskoxen, tundra hares, and arctic ground squirrels all give birth to young in May or June.

Curiously, lemmings, one of the most abundant tundra animals, do not produce young in spring. produce young under the snow in winter, and during mid to late summer when they can dig burrows into the soil. Lemmings spend the winter in the low spots on the tundra where snow accumulates in drifts. Spring meltwater floods their tunnels. As they are forced to move to high and dry spots with little plant cover, lemmings are vulnerable to their predators. Weasels, arctic foxes, and in some areas, snowy owls, prey on lemmings year-round. In spring they are joined by migrant jaegers, gulls, and short-eared owls. These migrants concentrate in areas where lemmings are abundant in spring, and some nest only in years when lemmings are abundant.

The activity on the tundra intensifies in mid-June as hordes of insects emerge and young birds begin hatching. The mosquitoes and other parasitic insects harass all the warm-blooded animals with their buzzing and biting. In northern Alaska, these insects eventually drive caribou from calving areas toward the coast and into the mountains where winds and cooler temperatures help reduce insect harassment. Any brown bears, wolves, or wolverines that followed the herds down from the mountains into northern lowland tundra return to the mountains with the caribou, too.

Shorebird chicks are ready to run within 10 minutes after hatching and by late June they are following their parents across the tundra in search of craneflies and midges. Geese lead their young from their nests to meadows where they can graze on sedges and other plants. Ducks lead their young from nests hidden amidst the tall sedges or tussocks of tundra, to lakes and ponds where they feed on cranefly larvae and other invertebrates that live in the muck at the bottom of the ponds. Loon nests are built right at the water's edge, so young loons can easily reach the water after hatching. Parent loons are soon occupied full-time catching enough fish for themselves and their young.

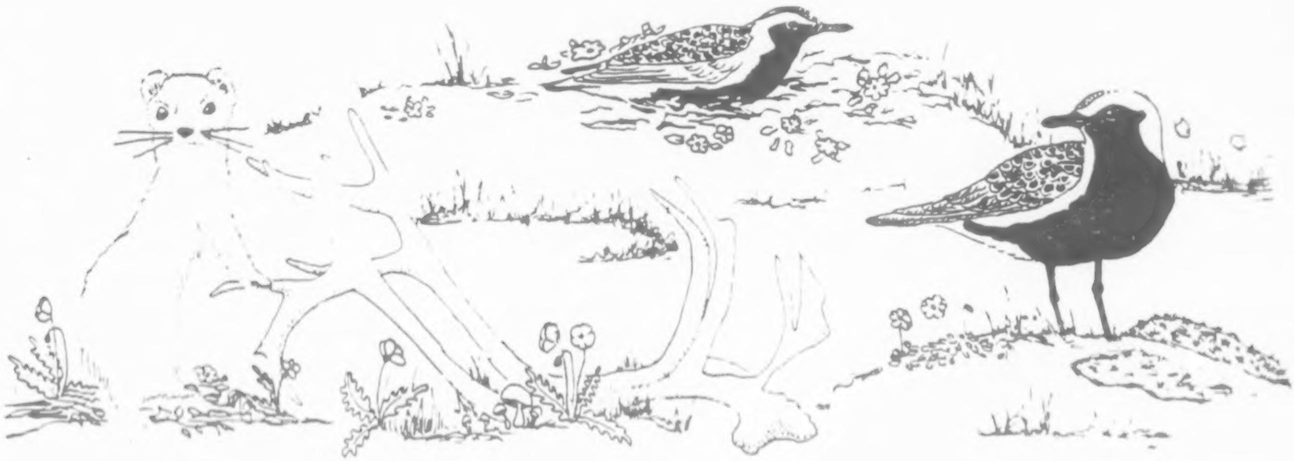
During June, geese whose nests have failed leave their nesting areas and migrate to molting areas in other parts of the tundra. The most important molting site in Alaska, Teshekpuk Lake, is far to the north of the nesting grounds of many geese, so many geese fly north in early summer. By then, many other birds are already flying back south. Some birds leave the tundra less than one-month after arriving. If lemming numbers are low, jaegers and short-eared owls do not nest and may begin drifting back south almost immediately after arriving. Since shorebird young can catch their own food, one parent usually leaves soon after the eggs are laid or the chicks have hatched. Shorebirds whose nests have failed also leave the tundra early. During July, hundreds of thousands of shorebirds move to the coast to fatten up before migrating south. Male eider ducks also migrate south from arctic tundra in mid- to late July.

In lowland tundra, temperatures may reach 70° F (21.1° C) or more on calm days during June or July, and the sun remains above the horizon for most of the day until 21 September. Frost, light snows, and cold winds can occur in any season, but their frequencies during August foretell the approach of winter.

Tundra plants begin preparing for winter in July or August. Instead of continuing to grow new leaves and flower buds as they do during June, tundra plants stop growing and instead begin storing sugars (made by photosynthesis) in their roots. In August and September they also begin reclaiming minerals from their leaves, and store these in their roots along with the sugars. The transfer of minerals from leaves to roots causes a change in leaf color. In northern Alaska, many lowland tundra plants have stopped photosynthesis and begin to turn brown, gold, or red by mid-August.

Frost and fall colors are not the only signs of fall. Most shorebird and songbird young are strong fliers by early fall; some are ready to migrate, or already on their way south by mid-August. Some species move to staging areas--pre-migratory concentration areas. Geese and ducks also begin concentrating at staging areas prior to flying south. Staging areas rich with food are very important to some species because migratory birds must nearly double their weights to have enough energy to complete their journeys to wintering areas thousands of miles to the south.

A mass exodus of birds occurs in August and September. By early October, when even the largest lakes and lagoons of northern lowland tundra are freezing over, all of the migrants have left. In arctic Alaska, the daylight period of each day shortens quickly. Another six to eight months of cold, snow, and howling winds must pass before the next burst of life can occur. In the meantime, the lemmings, muskoxen, weasels, arctic foxes, snowy owls, and hardy northern people have the lowland tundra to themselves.



Alpine Tundra

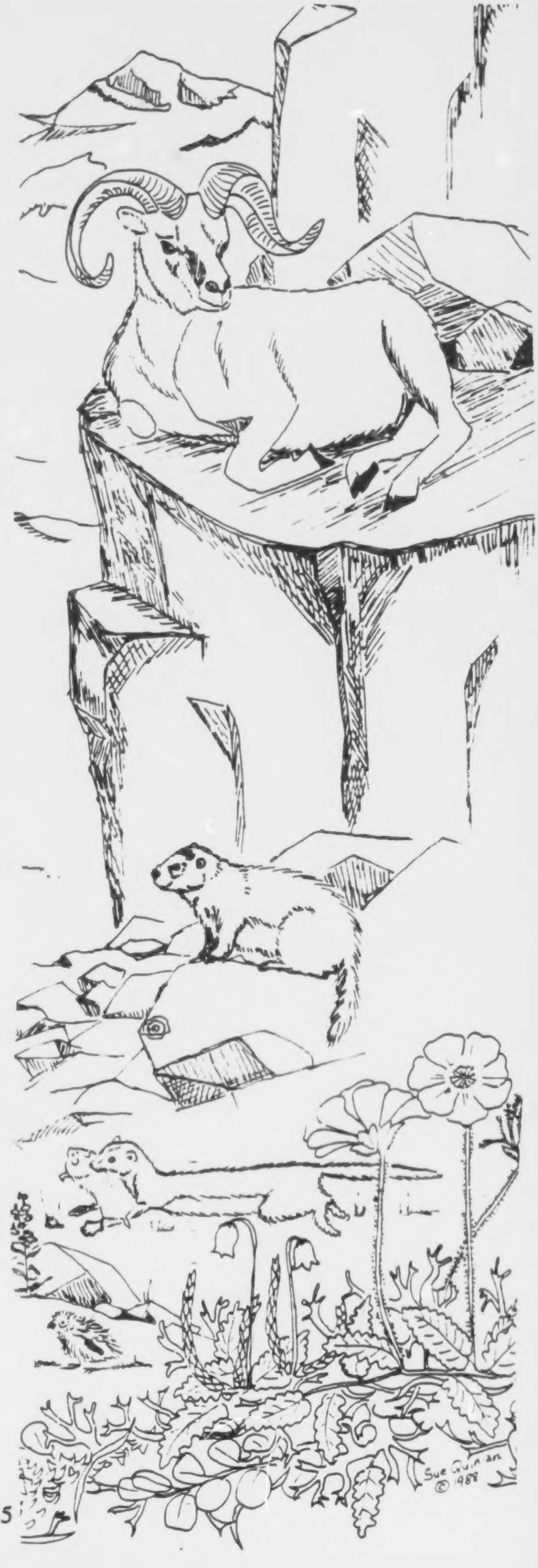
Patches of alpine tundra are scattered over the peaks, high ridges, and sloping plateaus of mountains throughout Alaska and the world. Each patch of alpine tundra is like an island surrounded by a sea of lower elevation habitats. Each "island" is slightly different from the others, but all alpine tundra sites have similar environmental conditions, and similar kinds of living things.

Temperatures year-round are colder than in nearby lowlands, and night-time temperatures can be below freezing year-round. Some alpine tundra sites (including those in southcoastal and southeastern Alaska) receive more precipitation, mainly in the form of snow, than most other environments on earth. In mountains of southcoastal Alaska, scientists have measured over 18.75 feet (5.7 m) of snow in just one month! Other sites, including most areas in the Brooks Range, receive less than 20 in (50 cm) of precipitation each year. Despite this wide variation in the amount of precipitation, most alpine tundra sites are dry.

Dry conditions occur for a combination of reasons. Most of the soil of alpine tundra is shallow due to wind and water erosion or landslides. Additionally, because of the cold annual and night-time temperatures, the soil surface is often frozen at night and in early morning; in some places, it is permanently frozen. As a result, little water is absorbed or stored in the soil. Instead, most rain and meltwater quickly rush downhill in fast-flowing streams. The high winds of alpine tundra speed evaporation and carry away much of the remaining moisture. Thus, most alpine tundra sites, particularly ridgetops and steep slopes, are very dry. However, snow accumulates in low-lying spots, on north slopes, and in sites protected from the wind. Soil on these sites may be waterlogged throughout the growing season, as melting snow provides a continuous supply of water.

For 6-8 months of every year, Alaska's alpine tundra environments are characterized by bitter cold temperatures and raging winds. The tundra seems fairly lifeless during this season because nearly all living things become inactive, or migrate to milder environments during winter. Only Dall sheep, (mountain goats in southern parts of Alaska), wolves, wolverines, pika, voles, and ptarmigan remain in alpine tundra and stay active throughout winter. Redpolls and gyrfalcons remain as long as conditions are tolerable, but during severe weather they often retreat to lower elevations.

Snow begins to melt on southfacing slopes in early spring, but snow melt continues throughout the summer. Windblown ridgetops and south-facing slopes may be snowfree most of the winter, or become snow-free in March or April. But snow accumulation areas (snow beds) may remain snow-covered for most or all of the summer.

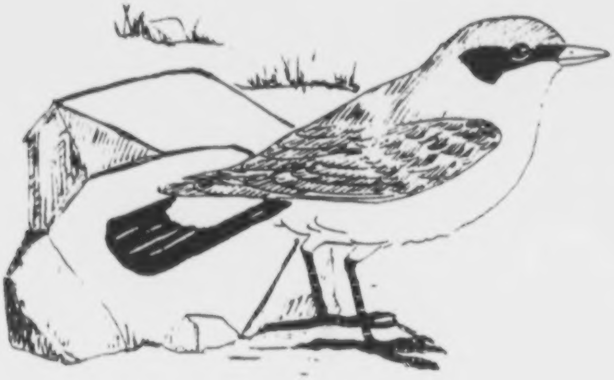


The raucous courtship calls of ptarmigan may echo from ridgetop to ridgetop by early April. Gyrfalcons and golden eagles, both sharp-eyed raptors, return to alpine tundra soon after the ptarmigan begin calling. Gyrfalcons prey on the ptarmigan, while golden eagles search for marmots or ground squirrels that have emerged from winter dens. These rodents sometimes emerge as early as mid-March. Brown bears emerge from their dens much later, usually in April or May, but sometimes not until June, depending on local conditions. At first, the bears make only short forays from their dens and continue to live off remaining winter fat.

During April and May, a wide variety of small migrant birds arrive. These include songbirds such as snow buntings, wheatears, longspurs, and horned larks, and a variety of shorebirds, such as whimbrels, golden plovers, surfbirds, and Baird's sandpipers. At first, the small birds must search the snow surface and the few snow-free areas for seeds and berries left from the previous year. Despite the shortage of food, all begin nesting almost immediately. The summer season is short, so any birds that do not begin nesting early are unable to raise young.

Seemingly within hours after the snowcover over them melts, alpine tundra flowers burst into bloom. Various species will continue to bloom throughout most of spring and summer, but the peak occurs during June. New leaves and flowers contain more minerals and energy than large old ones. So the appearance of new leaves and flowers throughout summer provides a continual feast for plant-eating animals. Dall sheep (or mountain goats in southern areas), ground squirrels, pikas, voles, marmots, ptarmigan, and brown bears feed on the nutrient-rich new plants.

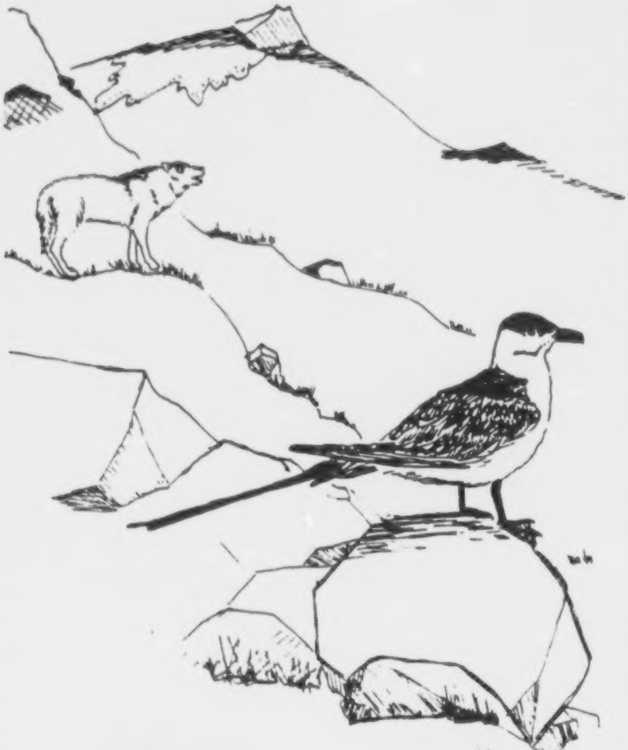
Soon after snowmelt, insect eggs andlarvae, dormant since the previous summer, resume development. Many insect larvae live for 2 or more years before turning into adult insects. Soon the air may be filled with mosquitoes and flies. The peak emergence of insects and the peak hatching of songbird and shorebird chicks coincide. This is important because the insects are the main food for alpine nesting birds and their young.



Thus, within a few weeks after the first trickle of meltwater, alpine tundra is carpeted with wildflowers, populated by nesting birds, buzzing with insects, and alive with the activities of all the animals that slept through winter. The frantic pace of early summer lessens during July and August. However, the food-gathering activities of many mammals intensifies as summer progresses. In some areas, the arctic ground squirrels must re-enter their dens and begin hibernation in August. Marmots and brown bears continue to gather food during the fall. All of these animals imust eat enough during the few months they are active to sustain them through the 6-9 months they spend in their dens. Pika and singing voles must not only gather enough food for themselves and their young, but in addition must gather and dry enough food to last an entire winter.

Caribou are year-round residents of alpine tundra in northern and central Alaska. In the Brooks Range, large herds wander through alpine tundra before snowmelt enroute to calving areas in lowland tundra. In mid-summer these herds return to the alpine in retreat from the relentless hordes of parasitic insects that occur in lowland areas at that time. On this passage, they feed on the more nutritious and succulent green plants.

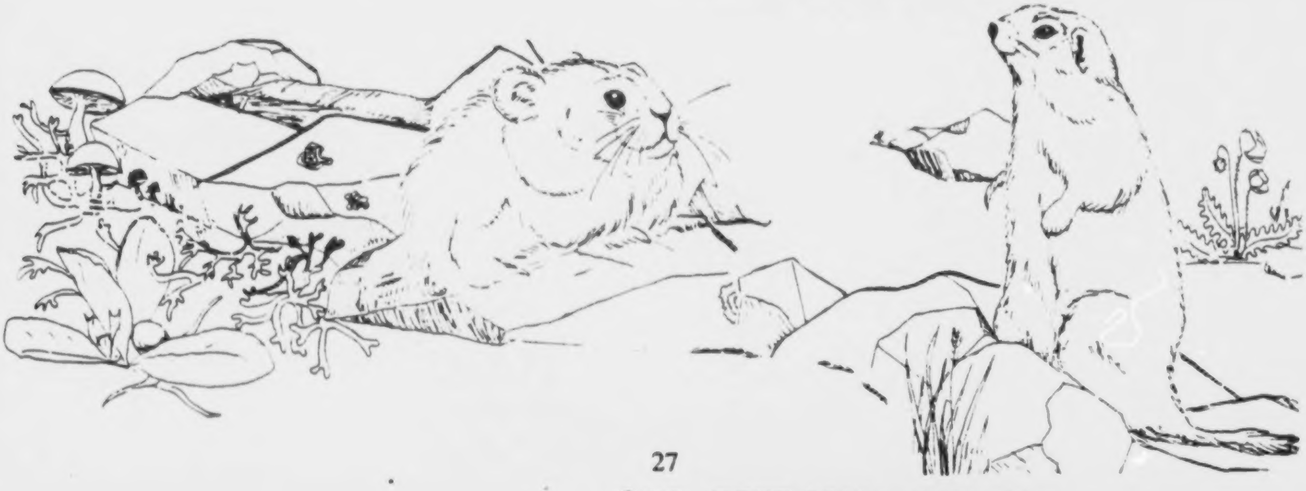
During mid-summer, daytime temperatures are often hot, so large animals like Dall sheep, mountain goats, and caribou frequent snowpatches to keep cool. These sites also provide some protection from the summer insect plague. Night-time temperatures in alpine tundra often drop below freezing even during summer, so most animals, large and small, seek some kind of shleter at night. Marmots, pikas, and singing voles stay warm in their dens in rock scree slopes. Arctic ground squirrels sleep in burrows in the soil beneath tundra shrubs. Dall sheep and goats retreat to cliff ledges with shrubs or boulders that block the wind. These sites also provide them protection from wolves and bears.



As summer proceeds, most alpine tundra sites become drier and drier. Lack of moisture forces many plants to enter winter dormancy even before cold temperatures and snow cover necessitate it. Fall colors of red, brown, and gold begin to appear in August. As day and night temperatures cool, insects become less numerous and less active. So insect-eating birds gradually leave to search for food in other areas. In late summer, ptarmigan gather in flocks prior to migrating. Those in the far north often fly hundreds of miles south to alpine tundra at lower latitudes. Those in more southern areas merely migrate to lower elevations and winter in or near forests.

Arctic ground squirrels quickly retreat to their burrows, but marmots, brown bears and pika remain active above ground even after the first light snows of fall. These latter animals are busy preparing for winter. Brown bears gorge themselves on berries and ground squirrels before digging winter dens in the hillsides. Ground squirrels and marmots enlarge the dens they have used all summer, and gather grasses and other plants to build winter nests. Pikas and singing voles, which remain active underground during winter, busily collect and dry various plants.

Winter returns to alpine tundra by mid-October or early November. Another 6 to 8 months of cold, snow, and howling winds will pass before the plants and insects will once again be active, before the migrant birds will return, and before the hibernating animals will awaken. But, life continues for several kinds of hardy animals. Dall sheep and mountain goats frequent the windswept ridges where they can still find plants to eat. Caribou paw craters through the snow to uncover lichens and other foods. Pikas and voles remain active beneath the snow. And wolves, wolverines, weasels, and gyrfalcons continue hunting for their respective prey. These remarkable animals are able to survive winter in one of the coldest and windiest environments in the world: alpine tundra.



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Introductory Activity 2.

Objective:

Students will be able to describe the similarities and differences between Alaska's alpine and lowland tundra environments, and be able to describe the variety and abundance of living things typical of each tundra type.

Skills:

SCIENCE: comparing, inferring; LANGUAGE ARTS: reading comprehension

Materials:

Descriptions and posters of lowland and alpine tundra, and tundra wildlife cards--all from this packet. (See pages 22-27 for tundra descriptions.)

Procedure:

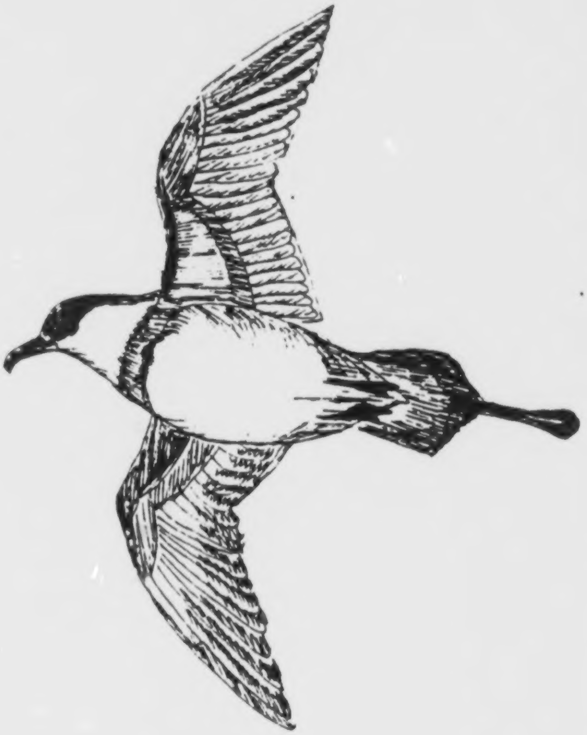
SUMMARY: Students will read descriptions of Alaska's lowland and alpine tundra environments, then use what they learned to compare and contrast the two kinds of tundra.

1. PREPARATION: Photocopy enough of the tundra descriptions so that each student can have one or the other to read. (Half the class can read the alpine description while the other half reads the lowland tundra description.) Review the teacher background information.

2. STUDENTS READ THE DESCRIPTIONS: This portion may be assigned as homework or done in class.

3. STUDENTS IDENTIFY SIMILARITIES IN THE TWO KINDS OF TUNDRA: (This may be done orally in class, or as a written assignment.) Ask students whether alpine and lowland tundra are similar or not. Ask them to list some of the similarities. Write these on the board as students describe them. Use questions to help students identify those they overlook. Students should recognize that both environments include air, water, soil, and sunlight; that both are cold, windy, and have long winters and short summers. They should also recognize that both environments are home to a variety of living things, including some similar kinds. Neither environment includes trees, and both have mainly low-growing plants.

4. STUDENTS IDENTIFY DIFFERENCES IN THE TWO KINDS OF TUNDRA: Next, ask students to name some of the differences between alpine and lowland tundra. Use questions to help them recognize that the terrains differ substantially (relatively flat versus mountainous), that day-night temperatures are more extreme in the mountains, lowland tundra receives less rain, but is more wet due to poor drainage and underlying permafrost. Students should also recognize that the long, dark winter is typical of northern lowland tundra, but not of all alpine tundra. Some different kinds of plants and animals live in the two different kinds of tundra, and students should recognize some of those typical of each tundra type. (The next step will increase and reinforce their grasp of this difference).



5. STUDENTS IDENTIFY THE ANIMALS AND PLANTS ON THE TWO TUNDRA POSTERS: Hang up the two posters of tundra and ask students to use the Tundra Wildlife Cards and other references to try to identify all the organisms pictured in each poster. (Or have students sort the wildife cards by tundra type.) Ask them to make a separate list for each poster. (This work can be done in groups.) When students have completed their lists, compare them to find out which of the pictured living things occur only (or primarily) in one tundra type.

Evaluation:

Have students complete Worksheet 2a and 2b.

TUNDRA RELAYS...................
........Physical Education / Science
...................Indoors / Outdoors

OBJECTIVES: Students will become more familiar with tundra organisms (or words) while practicing teamwork and physical education skills.
MATERIALS: Tundra Wildlife Cards, laminated and numbered with the organism names cut off or hidden (or see Variations); large open area; blackboard or large writing tablet with chalk or felt pen; physical education equipment as desired (see Variations)
PROCEDURE: Divide the class into relay teams of 4-6 students. Have each team stand in a separate line at one end of the playing area Spread the wildlife cards (prepared as described under Materials) on the floor or ground at the other end of the playing area. Write the names of 4-6 tundra organisms (depending on the number of students per team) on a blackboard or large chart. Explain to students that the objective of the relay is for each team to match the animal names to the correct pictures (cards). Each member of the team will have a chance to run to the other end of the playing area and pick up any card that they think shows one of the listed organisms. They must bring it back to their team for an OK. If the team agrees it is one of the animals on the list, they should write down the number on the card. The next player must then return the card to the pile and bring back another. Only one team member may leave the group at a time, and each student may only be a runner when it is his/her turn (he/she is at the front of his/her team's line.) No student may bring back more than one card, and the next relay runner may not leave without taking the card the former player retrieved. The first team to figure out the matching number for all 4-6 organisms yells out "Tundra! The instructor checks the team's answers; if they have made all correct matches they win 10 points for that round. If they have made an incorrect match, they lose 2 points for each incorrect answer. The round then resumes until one team gets the correct set of numbers.

VARIATIONS: Relay runners practice a physical education skill when travelling between their team and the card pile--e.g. dribbling, tumbling, skipping, climbing a rope, etc.

Instead of using the tundra wildlife cards, use photos of the animals; or use selected tundra glossary words and definitions, instead of animal names and pictures.

Alpine Tundra North and South......
..............Science / Language Arts
...................................Indoors

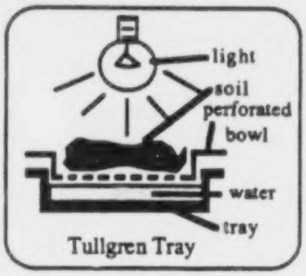
OBJECTIVES: Students will practice library research skills while becoming more familiar with the tundra environments and geography of the world.
SKILLS: library research, reading, writing, comparing
MATERIALS: Reference books on other parts of the world
PROCEDURE:
1. STUDENTS RESEARCH ALPINE ENVIRONMENTS: Assign individual students to research the alpine environments at various latitudes of the world, including some of the following: the high Andes in South America, high mountains in Africa, high mountains in Austrailia, high mountains in India and Nepal, the Rocky Mountains in the Lower 48 and Mexico, or Mauna Loa on Hawaii. Each student should try to find out the latitude of the site studied, the monthly average temperature and precipitation, the prevalence and speed of winds, the daily temperature variation, the types of living things typical of the area, and whether or not humans live in the environment.
2. STUDENTS WRITE REPORTS: After conducting their research, each student should write a report on the area studied. Encourage them to include graphs of the temperature and precipitation (similar to those presented in Worksheet 1b) and illustrations of the dominant plants and animals.
3. STUDENTS COMPARE REPORTS: Have students compare the various alpine environments they researched. What similarities did they find? What differences did they find? Can students make any generalizations about the differences between low latitude alpine sites and mid to high latitude alpine sites?
4. EXTENSION: Have students complete the Tundra People and Environments activity on the next page, then compare the amount of variation in alpine tundra versus lowland tundra. Which varies the least. Why?

TUNDRA PEOPLE AND ENVIRONMENTS...
INDOORS..SOCIAL STUDIES

OBJECTIVES: Students will recognize that tundra environments occur around the world, and will become familiar with the countries, environments, and lifestyles found in the tundra regions of the northern hemisphere.
MATERIALS: overhead projector, butcher paper, World Almanac, and a world atlas or maps of the world showing the distribution of tundra and the locations of countries and major cities, encyclopedias.
SKILLS: map-reading, geography, use of encyclopedia, atlas, and almanac; awareness of the similarities in the environments and cultures of people living in the north throughout the world.
PROCEDURE:
1. PREPARATION: This activity may be done as an extension of the Tundra Around the World activity on page-16 Lesson 1. Students can draw in political boundries on thier copy of the world map. Otherwise, you can use an overhead projector to trace a circumpolar map (showing the earth as viewed from above the north pole) on to butcher paper.
2. STUDENT LOCATE NORTHERN CITIES AND COUNTRIES ON A MAP OR GLOBE: Give students the following list of countries and cities. (Norway, Iceland, Finland, Sweden, Greenland, Great Britain, Poland, Scandinavia, Canada (Yukon Territory, Newfoundland, Northwest Territory), Soviet Union (Siberia), Nordkapp, Longyearbyen, Spitsbergen, Murmansk, Tromso, Vardo, Stockholm, Helsinki, Inuvik, Yellowknife, Barrow, Nome, Petropavlovsk, Warsaw, Novaya Zemlya, Svalbard, Bergen, Reykavik, Thule.) Ask students to locate these on a world map and add the political boundries of each country and the various cities to their map.
3. STUDENTS COMPARE THIS MAP TO A MAP SHOWING THE DISTRIBUTION OF TUNDRA IN THE WORLD: Discuss which of these countries contain lowland tundra. Which have the most? The least? Ask students whether they think the tundra in those other countries is similar to Alaskan tundra? Would it have the same plants and animals? Would the people live similar lifestyles?
4. STUDENTS RESEARCH THE LIFESTYLES OF PEOPLE LIVING IN OTHER NORTHERN AREAS OF THE WORLD. Have students use the encyclopedia and world almanac to find the answers to these questions. Divide the class into groups and assign each group to research the lives and tundra of a specific country. (Or assign individual students.) Ask each group to draw pictures, write a report, or prepare an oral report on the tundra, wildlife, and lifestyles of people in the assigned country or city. (Those who research a country that includes both forest and tundra need only describe the environment, animals, and lifestyles of the tundra region.) Encourage students to find out about the foods, clothing, housing, schools and work, industries, types of government, and problems of the people in the country they are researching. After students complete the assignment, have the class compare and discuss their findings. Do people who live in similar environments have similar lifestyles?
EXTENSION: Have students choose a country that contains tundra that they would like to learn more about. Have students write to another class, a newspaper, or to pen pals in that country. Encourage students to describe Alaskan tundra and their Alaskan lifestyle to their readers, and ask the readers questions about the tundra and lifestyles in their countries. Students might send photographs or artwork illustrating Alaska's tundra environments.With a little luck, the class might receive some fascinating responses from other northerners of the world.

LIFE IN THE TUNDRA SOIL.. INDOORS..MATH / SCIENCE

OBJECTIVES: Students will become aware of the number and variety of invertebrate animals that occur in tundra soil.
MATERIALS: A sample of tundra soil; glass jar, perforated bowl, tray with water, incandescent light; award for contest; hand lenses or dissecting scope
SKILLS: estimation, measuring
PROCEDURE:
1. Collect a sample of the top 2-5 inches of tundra soil. Place this in a glass jar, and place the jar in a conspicuous place in the classroom. Ask students to guess how many animals are in the soil sample. Each student may enter 1 guess, the student who gets closest will receive an award.
2. After students have all made guesses, force the invertebrates out of the soil sample using the Tulgren Tray shown at right. (Allow 24 hours to see the results.) Then have students help count the number of organisms that tumbled out. (Have students use a dissecting scope or hand lenses to look at the animals closely. Can students identify any of them? They should find mites and springtails at least.)
Award the student whose guess was closest to the number of organisms found. Discuss the number of invertebrate animals that scientists have found in samples of tundra soil (see background information, this Lesson).



Tullgren Tray

A TUNDRA FIELD GUIDE.. INDOORS...ART / SCIENCE

OBJECTIVES: Students will become more familiar with the wildlife of their local area.
SKILLS: reading, observation, art
MATERIALS: Tundra Wildlife Cards (this packet), Alaska Wildlife Notebook Series and other references on Alaska wildlife.
PROCEDURE:
1. SORT THE WILDLIFE CARDS: Have students review all of the tundra wildlife cards and sort out those organisms which might occur in the local area. (Some species, like pika, have a limited distribution in Alaska, and might not be found near your school.) Then, have students look up additional information on the organisms on the remaining cards.
2. STUDENTS WRITE AND ILLUSTRATE THEIR OWN FIELD GUIDES TO LOCAL WILDLIFE: Have each student or group of students make up a field guide to local tundra wildlife. (The guide could be just on birds, or another group of animals, or it could include all living things in your area.) The field guide should contain information on how to identify the each organism (coloration, traits), where to look for it (its habitat), how large it is, and what seasons it is present in your area. Students can get this information from local experts (long time residents or biologists), reference books, and from observations. The field guide should also contain illustrations (either drawn by students or use the illustrations on the cards).
3. "FIELD TEST" THE GUIDES. Take a field trip to a tundra area and see how many living things shown in the field guide students can find. Are there any common living things that students did not show in their field guide? Encourage students to find out what unknown plants, insects, or other organisms are, and then add them to their field guides. If carefully done, these guides could be valuable for younger students or future classes.

A Tundra Adventure........................ Indoors......................Language Arts

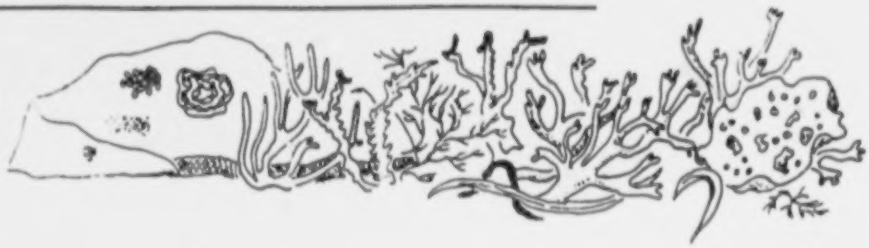
OBJECTIVES: Students will increase their awareness of alpine tundra and alpine tundra wildlife by writing a short story about a tundra animal, or about people living in a tundra environment.
SKILLS: LANGUAGE ARTS--writing, creativity, use of the library
MATERIALS: reference books about alpine tundra and tundra animals, pencil and paper
PROCEDURE:
1. EXPLAIN THE ASSIGNMENT: Ask students to write a story about a tundra animal. The story should include a main character, a setting of alpine or lowland tundra, and a plot. Discuss the term "plot" and suggest some possible plots (i.e. adventures) for a story. (hare escapes predators; caribou migrates, pika prepares for winter; a person gets lost on the tundra)
2. DISCUSS THE TERM "REALISTIC":Encourage students to write realistic stories. Discuss the term "realistic" carefully. Students should understand that in a realistic story, the animals behave like real animals (by not talking or wearing clothes, by eating the appropriate foods, by living in the appropriate habitat (not in human houses), and by doing appropriate activities). (For help with this concept, refer to the Project Wild activtity called"And the Wolf Wore Shoes".) In order to write a realistic story, students will need to know something about the animal they choose as the main character for their story, and something about the environment in which it lives. Encourage students to imagine they are the animal they are writing about and imagine what that animal might see, hear, smell, and feel. This will help them imagine things to write about.
3. STUDENTS RESEARCH AND WRITE THEIR STORIES: Have students follow these steps to write their story:
1. Choose a tundra animal to be the main character of your story. Research the facts about the animal and its life and think these over.
2. Make up a plot about a day, month, or year in the life of this animal. Quickly write your story down. Don't worry about spelling and punctuation at first.
3. Read the story out loud to another student or a parent. Discuss ways that it could be improved.
4. Rewrite the story incorporating the necessary changes. Check and correct spelling and punctuation.
5. If desired, draw an illustration of the main character or one event in the story.
4. STUDENTS READ THEIR STORIES TO YOUNGER STUDENTS OR EACH OTHER.

Discover Lichens................ ....Science, Art

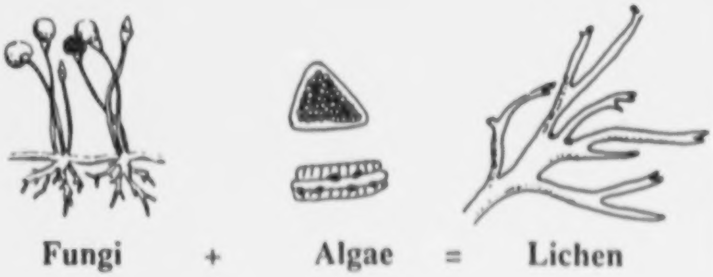
OBJECTIVES: Students will become more familiar with lichens.
SKILLS: Reading comprehension, observation of the local environment
MATERIALS: Discover Lichens Worksheet, page 33.
PROCEDURE:
1. Have students read the Discover Lichens Worksheet. Test their reading comprehension with the following questions:
What are the three kinds of lichens? (foliose, fruticose, and crustose)
What are lichens? (Two kinds of living things, a fungi and an algae or cyanobacteria, that live together.)
Where do lichens grow?
Where do lichens get the energy they need to live? (from the sun via photosynthesis)
Where do lichens get the minerals they need? (from precipitation)
What kind of lichens live longest? (crustose)
How long have some of the oldest lichens lived? (1000-9500 years)
2. STUDENTS COLLECT LICHENS
Have students look for and collect samples lichens from your local area. (Lichens are abundant in both tundra and forest areas.) Encourage students to find examples of all three types, and as many different kinds as possible. Have them observe the difference between a dry lichen and a wet one. Have them discover what happens when water is sprayed on a dry lichen? (They need to watch closely.)
3. EXTENSION: Some lichens can be used to make beautiful dyes of red, gold, blue, and brown. The dyes can be extracted by boiling lichens in water for 3-8 hours, or in some cases by soaking the lichens in ammonia. Different kinds of lichens yield different colors. (Some kinds don't yield bright colors, so you may need to experiment.) Soak wool or cotton cloth in the dye bath for several hours so that it can absorb the dye. For more information, consult: Dyes from Lichens and Plants, by Judy W. McGrath, Van Nostrand Reinhold, Ltd., Toronto, 1977.

Discover Lichens.......

Lichens grow on rocks, on trees, and on the ground. Many lichens grow in the tundra.



Lichens are made up of two kinds of living things, fungi and algae.

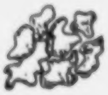


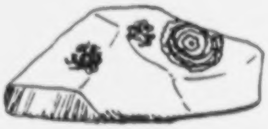
The fungi provide a tough shell for the algae, and soak up water and minerals from the surroundings. Some fungi give off chemicals that break down the rocks, wood, or soil upon which the lichens live.

The algae make food by photosynthesis.

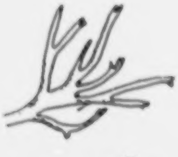
Lichens occur in three different forms.

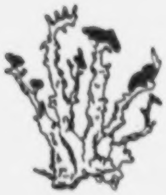
Crustose lichens grow like a crust on the surface of rocks and wood.

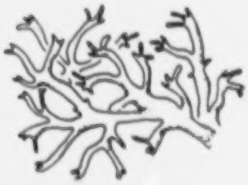




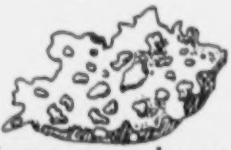
Fruticose lichens look like tiny shrubs or trees.

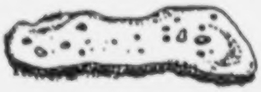






Foliose lichens look like strange, large leaves.





Lichens grow very slowly. Most grow only one, or a few millimeters each year. A millimeter is only this long: . Most lichens live for several years. Foliose lichens live for 10 years or more. Some fruiticose lichens live for 50 years or more. And some crustose lichens may live for 1000 to 9000 years. That makes them some of the oldest living things on earth.

Worksheet 2a.
Alpine Puzzle

Name______________________________________

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G S Q B W O L F E M I G R A N T S D I M J L P T A R M I G A N B
Y H O K L M M E L A I R O H S U O N I A T N U O M J G L E K P H
R O O S U N L I G H T S E P O L S S U L A T O W O J M O B N E O
F R T E F M H G D O C Q M N D B P M H P P H A H A K S A L A G R
A T I K B C N Q C L P M O U N T A I N G O A T I L N F A P C P N
L S U M J E G E M N G J P N P N J D L D E B K M I R O N M N F E
C U Q P Q A N D O Q B F I O F M B P M G F Q D B C M E M A L G D
O M S I A P Q G F J N A P A S S E L E E R T M R F G F T E K S L
N M O F P F Y J J Q Q P D E N I K I Q F O T K E N B F S A P A A
L E M K D L E N I R E V L O W D M K N H J P R L L Y A A E W Y R
L R P E O W A T E R P I P I T B P T O M R A M O R E L K J B R K
D S A P L A Q P H P O E A Q J L N E F C H B N D W P C O G C D C
P M O E P N E K D P O J L Q A E O A E P P G D R I E O B I F C L
D L A J B O F K P Q J F E I E H D M O H W I A N I Q S A B L B O
H I E K A N F E A O E L O V G N I G N I S E E D J B M U I M P N
C A J N O M W K G I N F M E F C A C N B T L O D L Q L F O O G Q
A T M B A P K O P K U F B H C B O T J A P P L C I O F G F L L O
R G N P G A O P R N B F G H C J E H E H K N C A C S C F Q G P Q
I N O H N Q O I G B B N D F J R B H L P C P K Y D G E E N I F K
B I I Q I E K I G H G C J L S P W I A A L I D A K M J D K Q J H
O R F I M L P E R M A F R O S T O G E O H I D L O C E A G F Q L
U P C G M M W I N D Y L K O Q S A E L G A E N E D L O G C H J Q
K S G J E F L S N E H C I L K R E P I P D N A S Q J Q R J C P J
E P L L L B M N F E G J P H K H I G H E L E V A T I O N S B O N
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Circle any words that accurately describe alpine tundra, describe a place where alpine tundra occurs, or which describe a characteristic of an alpine tundra environment, or name something you might find in alpine tundra. These 45 words are in the Tundra Word Search Puzzle--try to find them. You may use the Tundra Glossaryor a dictionary to find out the meaning of any words you don't recognize.

air
Alaska
alpine
barren
bat
brown bear
caribou
cliffs
cold
Dall sheep
dry
Dryas
forested
flying squirrel
fungi
golden eagle
gyrfalcon
high elevations
horned lark
lemming
lichens
long winters
long summers
loon
lousewort
low elevations
marmot
migrants
mosquito
mountain goat
mountainous
permafrost
phalarope
pika
polygon
ptarmigan
rocky
sandpiper
short summers
short winters
singing vole
soil
springtail
sunlight
talus slopes
treeless
tropical
warm
water
water pipit
weasel
wetland
wheatear
whimbrel
windy
wolf
wolverine
woodpecker

Alaska Wildlife Week Unit 6. Tundra © 1988 ADF&G

Junior / Senior High

Worksheet 2b.
Lowland Puzzle

Name_______________________________

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B D D P P L L O W L A N D N B B H Q F F A E L K A O I J B Q E N
R J B E M B O E K C M D K O P I N G O D F E J I P Q F A M E R N
I H W E R H S B U M B L E B E E K K B F A A I D F E M B C E F E
A D L H F I A M B O J G G O G M M E S O O G G F D M A N H O I J
S P R I N G T A I L O X Q D M C Q I A K H J L P E L G T M D C J
I N R E T A W I N A A L O M I G R A N T S H A M A C R I C H O C
D F C Q D F B K M M N S D F O Q E F T E P O L Y G O N E E K M H
L E M M I N G Q D P I G N S C S N P L R E I O O N K J N E A H D
D N P S K P H P B E I W E O Q I E D O H E O T A J B E L N N G L
G E K U C D L O C I E H E E W U T D B R S E T S O G D A D Q K B
O H A N B J K C J Q O E J T O B A C U D A I L I O L Q P M B M F
B C M L D N A C O F B L B F L G U W R T E L F E U R K H E C U S
B I O I L C O O L E N C P M K A E N L A I E A K S Q F D M D S A
O L J G G L L L B G K F T P D F N B T N J T B H C S S A E F K N
P E H H D E M M C P J U P C E E Q D H I E A A P P A E O M D O D
L G A T S N F A M E N F N A B D J E I E N E E L M H L P M R X P
O D Q A A E R H Q D O R E B A F H G E B A G H G H G J B E D E I
V E E J N I L H R J E J S R E T N I W G N O L B E G O A L H N P
E W F Q B P E A Q D H Q A R C T I C L O O N E K M R I I D N D E
R E K O I C H D I P O P A P H Y L F E N A R C I Q A O H B K D R
A C U N H A Q E M M O S S C A M P I O N O K D H K S O C P H Q H
H I I F R G D Q G F B H G G E H L O N G S P U R E Q L A N I B C
K Q D E E E C B Q K M S H O R T S U M M E R S L W O Y W O N S M
C E K F D F L K L P Q I J J N L B O T F L Y A Q J D D K K K K P
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Circle any words that accurately describe lowland tundra, describe a place where lowland tundra occurs, describe a characteristic of a lowland tundra environment, or is or name something you might find in lowland tundra. These 43 words are in the Tundra Word Search Puzzle--try to find them. You may use the Tundra Glossary a dictionary, or other references to find out the meaning of any words you do not know.

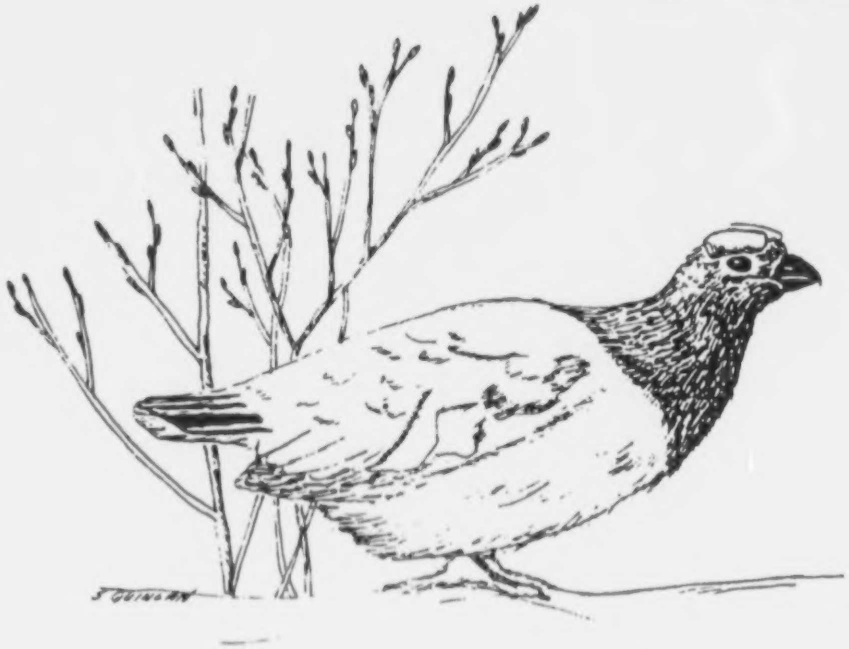
air
arctic
Alaska
alpine
arctic fox
arctic loon
barren
bat
blackfish
botfly
bumblebee
caribou
cliffs
cold
cranefly
eider
Dall sheep
flying squirrel
goose
high elevations
high latitudes
ice wedge
jaeger
lemming
lichen
long winters
long summers
marmot
migrants
mosquito
moss campion
mountain goat
mountainous
muskoxen
northern
permafrost
phalarope
pika
pingo
plover
polygon
rocky
sandpiper
short summers
short winters
shrew
snow bunting
snowy owl
soil
springtail
sunlight
talus slopes
treeless
tropical
tundra hare
water
weasel
wetland
woodpecker

Alaska Wildlife Week Unit 6. Tundra © 1988 ADF&G

Lesson 3.

Vocabulary:

adaptation, antifreeze, dormancy, hibernation, migration, staging



Objectives:

Students will be able to define the term adaptation and describe some of the adaptations of tundra plants and animals.

Background:

Biologists call the physical, physiological, and behavioral traits that help an organism survive in a particular environment, "adaptations". Organisms that live in tundra environments must have adaptations to help them survive and raise young despite the periodic severe cold, persistant winds, short growing season and other difficulties posed by this severe environment.

The following pages provide some specific examples of the amazing adaptations that allow specific living things to live and flourish in tundra ecosystems. (These pages may be used as student reading material, or for bulletin board displays.)

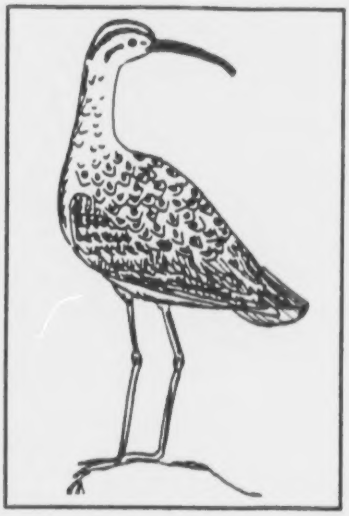
Migration is an adaptation for avoiding the severe winter conditions of tundra environments.

Many living things are able to live seasonally in tundra environments by avoiding the period of severe cold and strong winds by migrating to an environment with less harsh conditions. The seasonal gatherings and movements of large numbers of animals into and out of tundra environments are among the most spectacular natural events in the world. Each spring, huge flocks of shorebirds and waterfowl rush toward the tundra. Areas that were barren of life in winter can come alive with the movements and calls of arriving migrants almost overnight. These birds spread out over the tundra expanses to nest. Only in late summer and fall, when these avian migrants and their young gather together before hurrying south, is the surprising productivity of the tundra expanses revealed. The gathering places of migrants, called staging areas, occur in the same places year after year. Usually they are in locations that provide abundant food, so the migrants can fuel-up for their long-distance travels. Some migrant birds nearly double their weight with layers of fat before leaving.

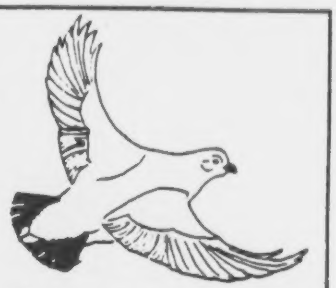
Many birds travel thousands of miles to wintering areas in Central and South America or Polynesia. The arctic tern migrates 10,000 miles (16,094 km) to winter in Antarctica. Some birds, like ptarmigan, migrate relatively short distances. They move south out of arctic tundra areas, and downslope from high alpine areas to low alpine or forested areas.

The migration of caribou from tundra areas to more southern forest environments is one of the best known examples of migration by a mammal. Their annual movements may, in part, be an adaptation for avoiding the severe winter conditions in tundra. The crusty snow pack that covers many tundra areas in winter makes it difficult for caribou to uncover food. However, some caribou do not migrate, but instead remain in tundra year-round.

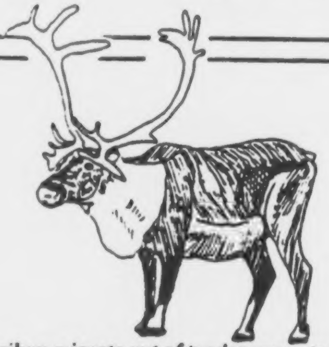
Many tundra fish also migrate. In fall, they move into places where the water does not freeze solidly in winter. Deep lakes, deep channels in large rivers, and spring-fed streams are important over-wintering areas for tundra fish.



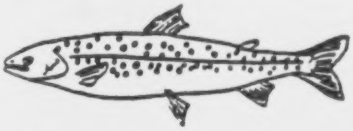
Whimbrels nest in tundra but migrate to spend the winter on the Pacific coast from California to Chile. Most shorebirds migrate thousands of miles to southern wintering areas.



Ptarmigan migrate out of the northernmost tundra regions to winter in the alpine tundra and forests of central Alaska.

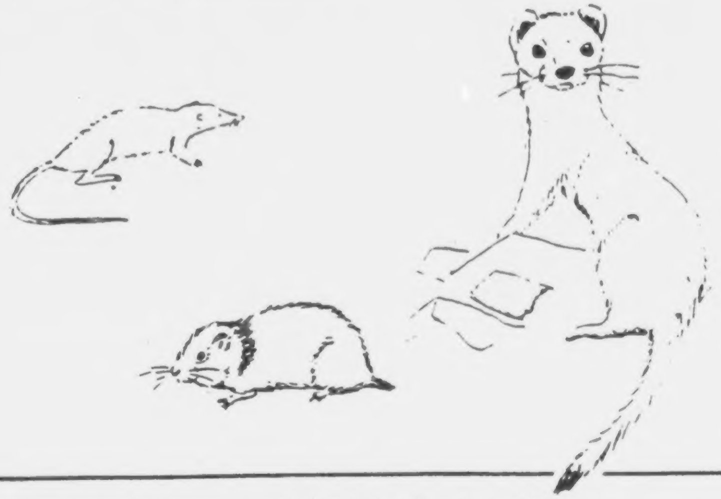


Caribou migrate out of tundra areas to winter in more southern taiga and forests.



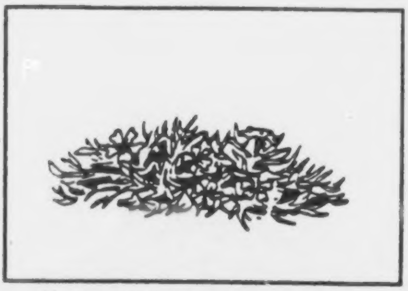
Tundra fish, such as arctic char, migrate to places where some water remains liquid throughout winter.

Many living things remain on the tundra year-round, but avoid the severe winds and cold.



Lemmings, voles, shrews, weasels, arctic ground squirrels, insects and most plants survive the winter winds and cold by living beneath the snow. Temperatures under a blanket of deep, soft snow are usually 20° F (34° C) warmer than the air temperature above the snow. However, in tundra areas with crusty, windblown snow, the under snow temperature may drop to -31 °F (-35° C).

The small mammals, insects, and plants that live in tundra cannot make long distance journeys to avoid the severe winter conditions of tundra. Many of these winter residents avoid the severest winter conditions by remaining beneath the snow. For example, lemmings tend to concentrate in areas where the snowpack is greatest. The snow shelters them from the wind. It also offers some protection from the cold of winter. However, the dense, wind-packed snow of arctic tundra is a poor insulator and provides only limited protection from the cold. (In contrast, where the snow is protected from wind, it is deeper and less dense and provides much better insulation.)



Air temperatures near the ground are warmer and winds are slower near the ground surface. Many tundra plants, such as moss campion, grow in low, flat mats or cushions to take advantage of these milder conditions.

Some animals, like the arctic ground squirrel, move underground for winter. Soil, like snow, provides insulation against the cold and wind. Many plants have a similar adaptation; their above ground parts die back each winter, but their main growth and energy storage is in their underground roots, which, sheltered by the soil and snow, survive the winter cold and winds.

Environmental conditions on the tundra are most severe during winter, but cool temperatures and strong winds during summer also pose problems to living things. The adaptations of many living things enable them to avoid the cold and wind year-round. For example, many tundra plants are small and grow in flattened, cushion-like forms. Due to friction, the wind speed an inch or two above the ground is much less than the wind speed farther above the ground. The air is also warmer near the ground than above it because soil absorbs and radiates heat from the sun. Many kinds of insects live their entire lives in the shelter of ground plants, thus avoiding the most severe cold and wind of the tundra. Wingless forms of many insect groups are most common in tundra environments. Arctic ground squirrels and brown bears select south-facing slopes in which to dig their underground dens. These sites are warmer than north-facing slopes during fall and spring.

Wingless insects are common in tundra environments. They spend their entire lives in the shelter of soil, mosses, or other plants.

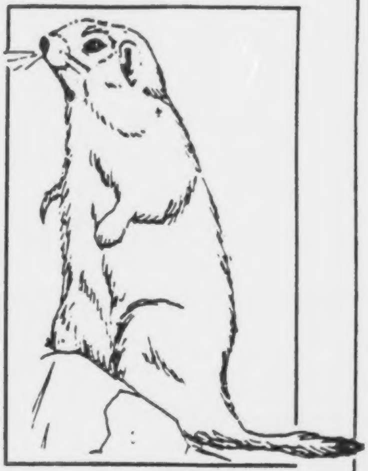
Food is scarce during the 8 months of winter, so tundra animals must have adaptations that help them survive with little food.

Plants, insects, and microscopic organisms simply cease functioning during winter. They do not move, grow, or breathe during the winter, so they have no needs for food. Birds, mammals, and fish cannot survive unless they continue to breathe, so they cannot become completely dormant.

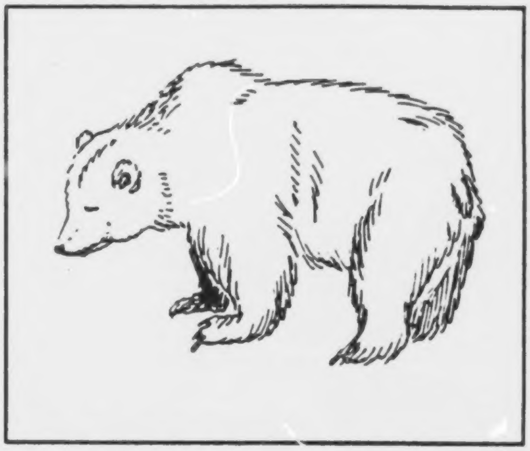
Some animals survive, not by ceasing to function, but by reducing their functions to the minimum needed for survival. For example, arctic ground squirrels and marmots hibernate. During the 7-8 months of winter, an arctic ground squirrel remains inactive, its heart beat is reduced from 200-400 to 7-10 beats per minute, its body temperature is reduced from 97 to 62 °F (36 to 17°C), and its breathes only 3 times each minute instead of 60 times per minute. While dormant, a ground squirrel uses 98 percent less energy than while awake. Brown bears also survive winter by becoming dormant; their heart rate is reduced from 50-60 to 20 beats per minute, but their body temperatures are not reduced, so scientists do not consider their dormancy a true hibernation.

Arctic ground squirrels, marmots, and brown bears must store enough energy during summer to maintain their body functions throughout their winter dormancy. All of these animals store the needed energy as layers of fat. A brown bear (in tundra habitat) that weighs 300 lbs (136 kg) in fall emerges from its den in spring weighing less than 200 lbs (91 kg), because it uses its fat (or energy reserves) while dormant.

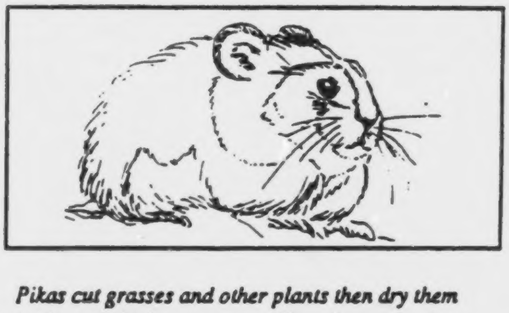
Many tundra animals are not dormant during winter, however. Lemmings, for example, remain active and even raise young during winter. They survive by feeding on the energy-rich buds, stem bases, and rhizomes of dormant plants. Pikas and singing voles remain active during winter too; they survive on food they stored for winter use. During summer, pikas busily gather and dry grasses in the sun, then store the hay in caches near their nests. Singing voles build large piles of grasses and other plants for winter food.



Humans may die if their body temperatures drop below 90° F (32° C) for even a short time, but arctic ground squirrels drop their normal 97 F (36° C) body temperature to only 62 F (17° C) during hibernation. This greatly reduces their needs for energy.



Brown bears only eat during 4-5 months of the year. Some may lose up to 30% of their body weight during winter when they must live off of the energy stored in their fat.



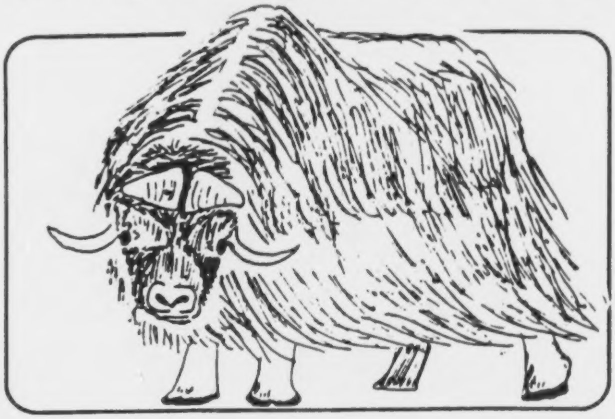
Pikas cut grasses and other plants then dry them in the sun during summer. They then store the dried hay underground as a winter food supply.

Most tundra organisms have insulation to help them stay warm.

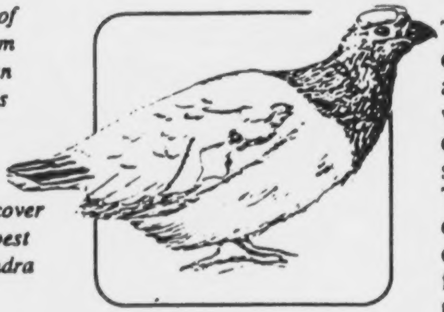
One of the most obvious adaptations for life in a cold environment is insulating feathers or fur. Most tundra birds and mammals actually have two coats. Their outer coats are made up of tough, coarse water-repellent feathers or guard hairs. Their inner coats are made up of soft, fluffy feathers or hairs that trap air. Ptarmigan can keep their body temperatures at 104° F (40°C), (without increasing their respiration rate) even at temperatures of -29° F (-34° C). Caribou and muskoxen have hollow hairs that are fatter at the tips than at the base. This shape helps the hair trap a layer of air next to the body. Trapped air provides excellant insulation.

Tundra bumblebees provide a fascinating example of the adaptive value of an insulative coat. Insects are cold-blooded or poikilothermic organisms, which means that their body temperatures are closely related to the temperature of their surroundings, and rise and decline accordingly. The chemical reactions necessary for movement do not occur at cold temperatures, so most insects can not move unless the temperature is above freezing. However, dense hair on the bodies of tundra bumblebees slows heat loss from their bodies to the air. Certain bumblebees "shiver" their flight muscles to generate heat. This heat is temporarily trapped within the bee's velvet coat. Certain bumblebees can keep their body temperatures 68-86°F (20-30° C) above air temperatures, and thus can easily be active when other insects are too cold to move.

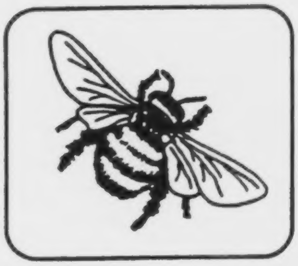
The furry and wax-like coatings of certain tundra plants are also adaptations that enable the plant to resist cold and wind. Fine hair or fuzz slows the wind and thus reduces the "wind chill" or loss of heat. The fine dense hair around the flowers of the wooly lousewort not only reduce wind chill, but also trap heat from sunlight like the glass of a greenhouse. The flowers are thus surrounded by relatively warm air, sometimes 34° F (20°C) warmer than the environment. This is quite important because the process of cell division, necessary for the formation of seeds, can not occur at cold temperatures. The waxy coating of many plants reduces water loss and evaporative cooling by the wind. Many tundra plants retain, rather than shed, their dead leaves each year. The dead leaves serve no apparent purpose except they insulate the fragile new buds from the wind and cold. Grass tussocks provide a good example of this.



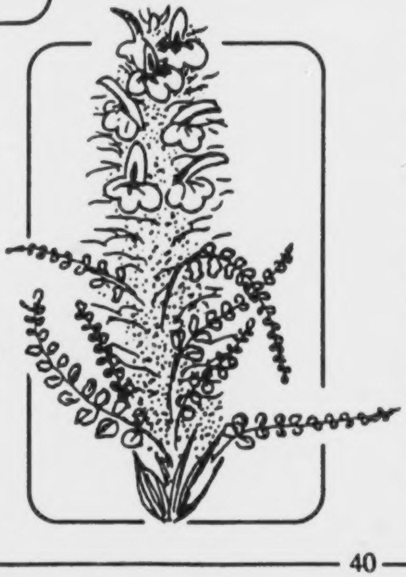
The long, dense fur of muskoxen helps them stay warm even when the air temperature is -40°F (-40° C).



Ptarmigan, whose feathery coats even cover their feet, have the best insulation of any tundra bird.



Tundra bumblebees have dense velvet-like hair that helps them keep the heat released when they move their wing muscles.



Wooly lousewort, a tundra plant, is covered with hairs that help block the wind and trap warm air around its leaves and flowers.

Some tundra organisms make antifreezes.

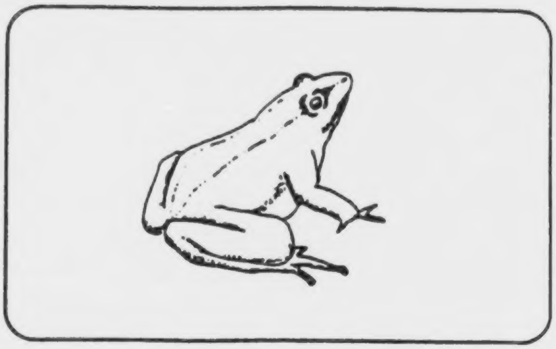
Most people have heard of the antifreeze which we add to the water in our vehicles during winter to prevent the water from freezing. This antifreeze is made up of ethylene glycol, a fluid which freezes at a lower temperature than water. By mixing it with water, we can lower the freezing temperature of the water. Most living things are made up of 70% water. When water freezes, it expands and forms ice crystals. If this occurs in a living organism, the cells are damaged. Repeated freezing and thawing are particularly destructive of living tissue. Yet repeated freezing and thawing temperatures are characteristic of the milder summer season in tundra environments.

Some organisms have overcome this problem in essentially the same way that we protect the water in our vehicles. They produce chemicals that lower the freezing temperature of cell fluids. These antifreezes prevent the formation of large ice crystals within the cells even at very low temperatures.

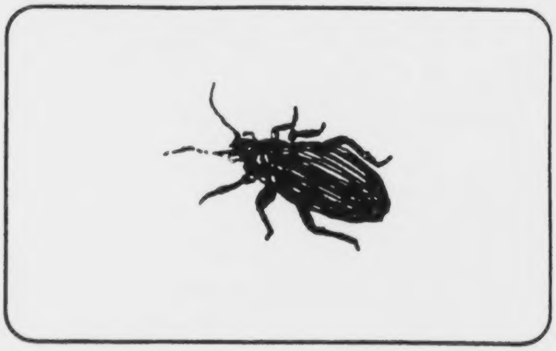
Because of the antifreezes in their blood, wood frogs can survive temperatures of 21°F (-6°C). Most arctic insects produce glycerol, which is an effective antifreeze. If cooled slowly, certain arctic insects can withstand tempertures of -76°F (- 60 °C).

Some tundra fish also have antifreezes. Alaska blackfish can survive temperatures as low as 4° F (-20° C), as long as their bodies are not completely frozen.

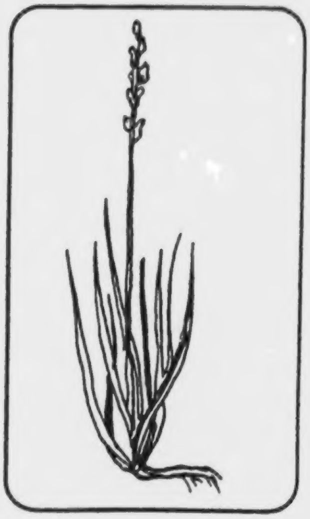
Plants need antifreezes not only to prevent freezing, but also so they can make enough food to survive. The process of photosynthesis requires water, so many plants cannot function if the temperature is below 32° F (0°C), the freezing point of water. But air temperatures in tundra environments often drop below zero in spring, fall, and even summer. Many tundra plants, like Dupontia fischerii, a tundra grass, are able to photosynthesize at temperatures of 25°F, (-4°C). because antifreezes which they produce keeps cell fluids liquid even at this low temperatures.



Wood frogs can withstand temperatures of 21 F (-4C).

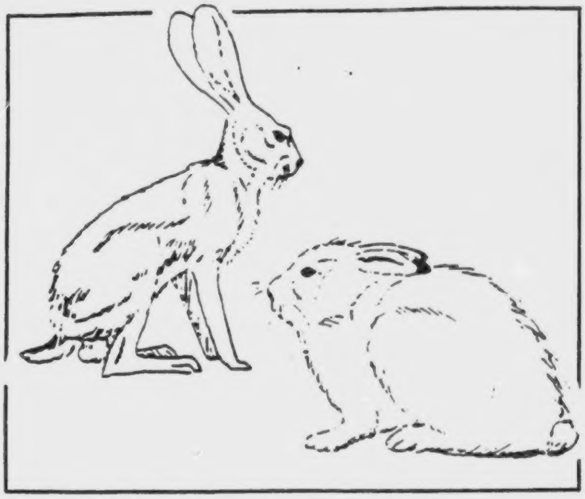


Some tundra insects can withstand temperatures of - 76 °F (-60°C).

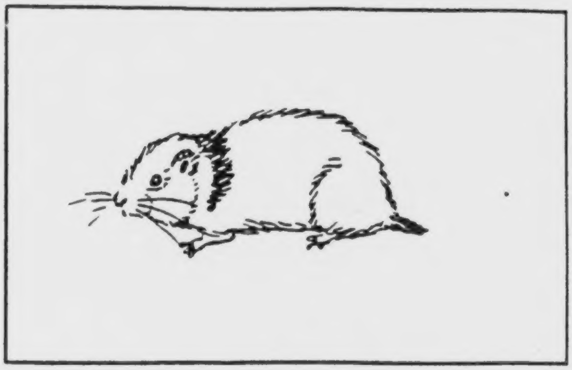


Many tundra plants, like Dupontia fischeri can photosynthesize sugars at temperatures below the freezing point of water.

Large size and short appendages are adaptations that help tundra animals keep warm.

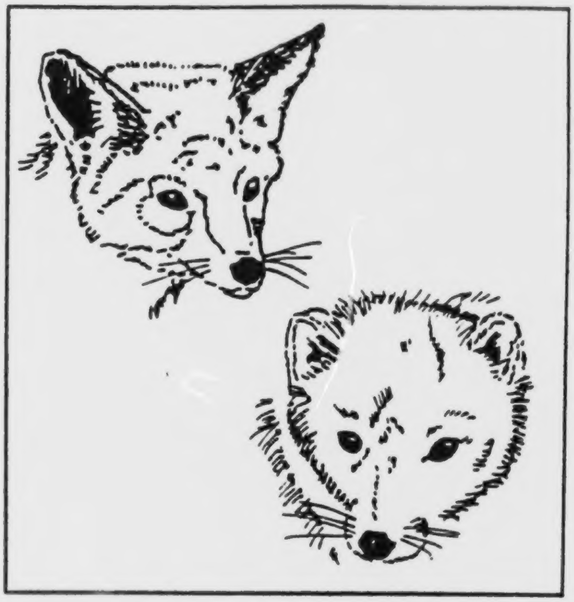


Tundra hares are larger and have shorter ears than hares that live in hot environments.



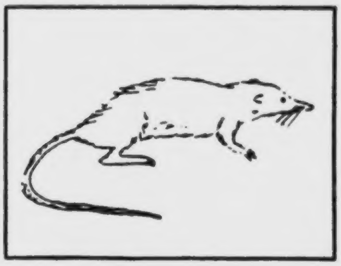
Lemmings are larger, and have smaller ears and tails than most other mouse-like animals.

Biologists have noticed that many tundra birds and mammals are larger and have smaller appendages than similar species living in warmer environments. For example, tundra hares are among the largest hares and have shorter ears and legs than desert hares (called jackrabbits). Similarly, arctic foxes have shorter ears than desert kit foxes. Even lemmings, though small, are larger, and have smaller ears and tails than most other mouse-like animals. Large size and short appendages are adaptations that reduce heat loss and resist cold. The amount of heat lost increases as the proportion of surface area exposed to the environment increases. Since small animals have more surface relative to their weight than large animals, they lose heat more quickly. An animal with long legs, ears, or a tail has more surface area than an animal of the same size but with shorter appendages.



Arctic foxes have shorter ears than desert kit foxes.

However, small size can also be an adaptation for survival on the tundra. Why? Because a small organism can survive on a smaller, total amount of food than a large organism (of the same species). Very small organisms can also live under the snow and avoid the most severe conditions of winter. Shrews, the smallest of all mammals, are able to live in tundra of arctic Alaska.



Small animals like shrews are able to keep warm despite their small size, in part because they can live under the snow.

The coloration of living things in the tundra are adaptations to their cold environment. Which is warmer, dark or light?

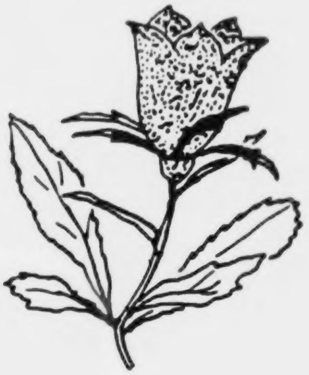
Dark colors absorb heat, while light colors reflect it. Thus, one might expect that organisms that live in cold tundra environments would be darker than organisms living in warmer environments. A study of flowering plants showed that the proportion of dark colored flowers is greater in the tundra than in warmer environments. Many tundra flowers are purple, blue, or yellow because these colors absorb more heat than white. Certain tundra insects are darker than related species that occur in warmer habitats. The value of dark color can be increased by an organism's behavior. For example, many butterflies bask in the sun with their dark wings spread wide to absorb heat.

Thus, among organisms whose temperatures are strongly influenced by the environment, dark colors can be an adaptation for survival in a cold environment.

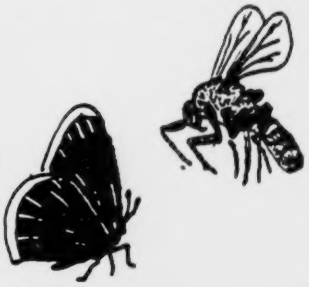
However, the light coloration of arctic poppies (and other flowers) is an adaptation to the cold environment, too. The flowers of these plants are heliotropic, meaning they turn to face the sun. The shape of the light petals are such that they reflect sunlight toward the flower center where the seeds are produced. Several kinds of insects bask in the centers of these flowers, and benefit from the focused solar heat.

Many animals that maintain warm body temperatures (homeotherms), such as birds and mammals, have light, or white, feathers or fur. Their light coloration also may be an adaptation for staying warm. These animals generate their own heat, but lose heat when it radiates to their surroundings. Light colors radiate less heat than dark colors, so light fur and feathers actually may help warm-blooded tundra animals keep warm!

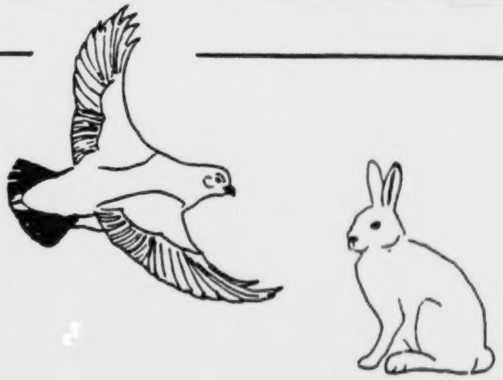
White fur and feathers also camoflauge animals in the snow. Thus white coloration may help collared lemmings, ptarmigan, and snow buntings escape their predators, and help snowy owls, weasels, and arctic foxes sneak up on their prey.



More tundra plants have blue or purple flowers than plants in warmer environments.

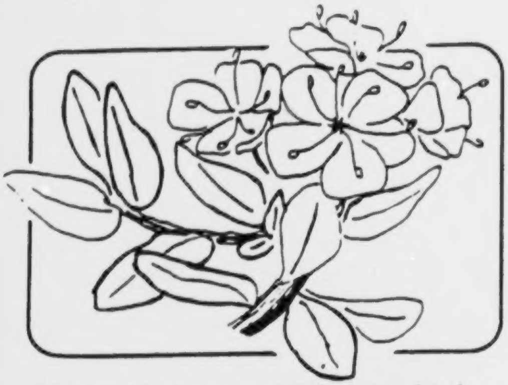


Most tundra insects are darker than related insects in warmer enviornments.

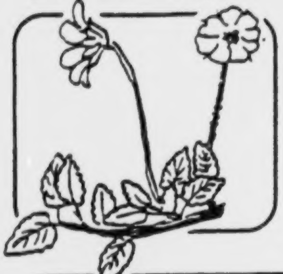


Many warm-blooded animals that live in tundra have white fur or feathers during winter.

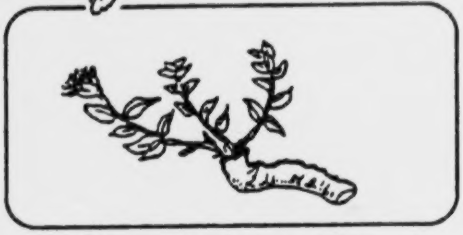
Tundra plants have adaptations that allow them to survive even though they can only be active during 3-4 months of the year.



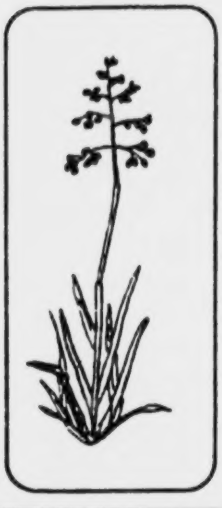
Most tundra plants are several years or decades old. The age of some woody tundra plants has been estimated at 200-300 years base on a count of thier annual rings.



Tundra flowers bloom from buds that are 1-2 years old.



Many tundra plants reproduce by rootstocks or runners.



The seeds of Poa alpina germinate and grow while still nourished by the parent plant.

The short growing season of tundra environments poses a problem to most living things, and severely limits the productivity of tundra. All living things ultimately rely on plants (and other organisms) that are able to make food sugars by photosynthesis. Plants can only photosynthesize food if they have adequate supplies of sunlight, air, and liquid water. Tundra plants cannot grow during most of the year due to the low intensity of sunlight, snow cover, and temperatures below the freezing point of water.

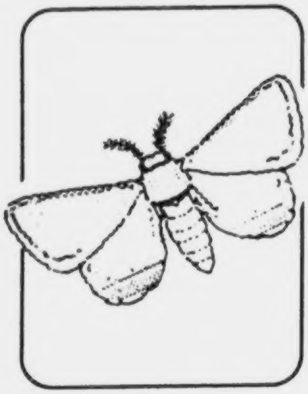
Tundra plants have several adaptations that allow them to survive despite the short season. First, when conditions are right for photosynthesis, tundra plants can actually make food faster, and grow faster than plants adapted to other environments. They are well adapted to photosynthesize at low temperatures and low light intensities. This ability enables them to make better use of the short growing season, but the season is still too short and cold for most plants to grow very much. Most tundra plants require many years to grow the same amount that a plant in a milder environment grows in a single year.

Most tundra plants store sugars in their roots each summer, so that they can begin growing new leaves even before the snow over them melts away. This is advantageous because it allows them to begin photosynthesis as soon as they are exposed to sunlight in spring. Many tundra plants keep their leaves from year to year. These "evergreen" plants can also begin photosynthesis as soon as they are exposed to sunlight in spring.

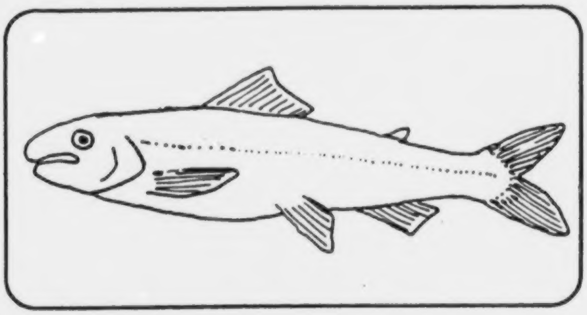
Many tundra plants must grow for a decade or more before they have enough leaves to store up the energy required to form flower buds. Then, most require 1-3 years to develop the buds. Nearly all tundra flowers come from buds that are 1-2 years old. The fragile flower buds develop underground, or are enclosed by dead leaves, so they are well-insulated during the cold winters. When spring comes, the tundra can literally burst into bloom because the flower buds were formed in previous years.

Because tundra plants need so many years to develop from seed to flowering size, many plants reproduce by rootstocks or runners, instead of, or in addtion to seeds. The tiny plants that sprout from the rootstocks are identical to (or clones of) their parent. The "clone" plants are nourished by the parent plant, which has many leaves, until the clones have many leaves of their own. Some tundra plants, like the grass, Poa alpina, produce seeds that germinate and begin to develop while still attached to the parent. This is an advantage because the young plants that drop off the parent already have tiny leaves and can begin photosynthesis right away.

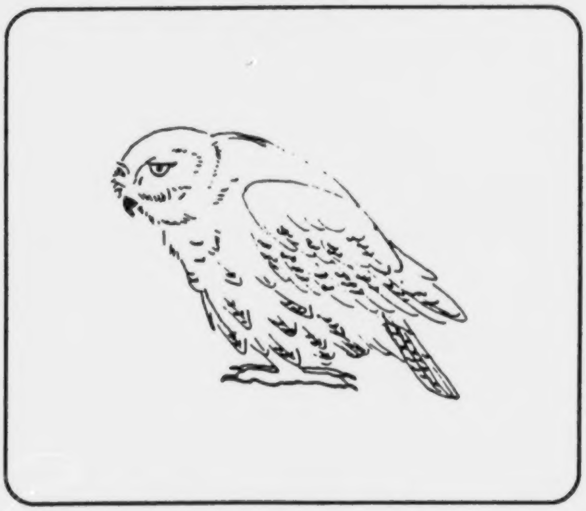
Most tundra animals grow slowly and raise young only when conditions are suitable. These adaptations help them survive the short growing season and harsh environment.



Most tundra inscets grow very slowly. Certain moths live 5-10 years before becoming adults.



Lake trout that live in tundra lakes do not reach adult size for 8 to 10 years because of the short growing season, low temperatures, and scarcity of food.



Predatory birds like snowy owls do not nest when lemmings, their main prey, are scarce.

Growth and reproduction require food--energy and minerals. Any organism that grows faster than it is able to obtain food starves to death. Similarly, an animal that produces young when food or other conditions are unfavorable reduces its own chances for survival, as well as the chances for survival of its offspring. Both the availability of food and the weather of tundra environments are quite variable. Thus the ability to adjust growth and reproduction according to the availability of food and other environmental conditions is an adaptation that allows certain organisms to survive in tundra environments.

Most cold-blooded, or poikilothermic, tundra organisms grow slowly or not at all when conditions are unfavorable, and they do not reproduce until they reach a certain size and conditions are appropriate. For example, certain arctic moths may require up to 10 years to develop into adults. In milder environments, the same species can reach adult size in 1-2 years. A similar variation in the growth of fish occurs. Lake trout that live in large, relatively productive lakes grow to adult size in 5-6 years, but the same species living in less productive tundra lakes may require 10 years to reach adult size.

The growth and reproductive output of most mammals and birds also varies according to environmental conditions. For example, brown bears that live in the northern tundra of Alaska do not begin breeding until 8 years old, and give birth to only 2 young every 4 years. This is quite slow compared to the brown bears that live in the productive environment of southcoastal Alaska; they begin breeding when 3-4 years old, and give birth to 2-3 young every 3 years. Some migratory birds, including geese, swans, and shorebirds, do not lay eggs, or lay fewer eggs, when snow melt occurs late. Instead, they may skip breeding for that year, essentially saving their energy for another year. Predatory animals, such as jaegers, snowy and short-eared owls, rough-legged hawks, arctic foxes, and weasels produce more young in years when lemmings, their main prey, are abundant. Some of the avian predators on lemmings do not even nest in years when lemmings are scarce.

Introductory Activity 3.

Objective:

Students will recognize that the living things that occur in tundra have special traits and behaviors (i.e. adaptations) that enable them to survive in this environment.

Skills:

SCIENCE: measuring, comparing, inferring, predicting, hypothesizing
LANGUAGE ARTS: reading, speaking

Materials:

Tundra Adaptation Cards from the Tundra Wildlife Cards section of this packet, the Adaptations Report (page 47), blackboard, chalk. Each group of 2-3 students will also need the materials and instructions for one of the following experiments.

Experiment 1: Size and Heat--2 thermometers, large and small containers made of the same material (pails, cans, or plastic food containers), warm water, access to outdoors or a refrigerator, instructions

Experiment 2. Long Ears and Heat--1 pair rubber or plastic gloves, several rubberbands, 2 thermometers, a pail of warm water, a measuring cup, instructions.

Experiment 3: Color and Heat--2 identical tin cans, 1 painted black and 1 painted white, 2 thermometers, warm water, direct, bright sunlight or an intense grow-light, instructions

Experiment 4: same as #3, except the light.

Procedure:

SUMMARY: Students will conduct experiments to determine the effects of color, size, and shape on heat loss and use the results of their experiments to explain some of the physical characteristics of tundra animals.

1. PREPARATION: Gather and group the materials needed for each experiment and for each group of students. Divide the class into groups of 2-3 students and have each group do one of the experiments. Each experiment requires 20-30 minutes. (While waiting to find out the results of their experiments, students may be working on step 2.) Students should record the data from their experiments.

2. STUDENTS EXAMINE THE ADAPTATION CARDS: Write the definition of an "adaptation" on the board and give each student or group an Adaptations Record. Then, place the adaptation cards on a table. Explain that each card describes the adaptations of a particular organism. Students should read each card and select those which describe an organism found in tundra. For each of these, students should hypothesize (make an educated guess) how each of the traits described might help the organism survive in tundra. Students should record each described trait (as an example of an adaptation) and their hypotheses about the value of the trait on the Adaptations Report. If students can not think of a value for the described trait, they should leave the value space blank. (Note: Some traits are shared by several animals. Students should list the names of all the organisms that have the given trait in the last column, rather than listing the trait several times.)

3. DISCUSS THE EXPERIMENT RESULTS: Have each group orally present the results of their experiment. Student reports should include their hypotheses, methods, results, and conclusions. Use the questions provided at the end of each experiment instructions card to help students apply their experiment findings to understand animal adaptations. Are students able to recognize, based on their experiments, that large size, small appendages, and both dark (in summer) and light coloration (in winter) are adaptations that reduce heat loss? (Students should include these traits and their values in their lists of tundra adaptations.)

4. DISCUSS THE ADAPTATION CARDS: Discuss how particular traits of tundra animals are adaptations. Do students recognize that different kinds of living things sometimes have similar adaptations (e.g. arctic foxes and lemmings both have relatively short ears)? Do students recognize that in other cases, different organisms have very different adaptations to the same environment (e.g. migratory birds are adapted to tundra environments in a different way than species that overwinter)?

Discuss some of the organisms that live in other environments. Do students recognize that these organisms also have adaptations--traits that help them survive in the environment where they live. Discuss some of non-tundra organisms described; can students guess the kind of environment for which each is adapted?

Ask students whether an animal or plant with adaptations for life in a tundra environment could survive in a desert or rainforest. Or vice versa? Why not? (Many of the traits that allow an animal to survive in a particular environment would be disadvantageous in a different one. For example, an arctic fox would die from over-heating in a desert.)

Evaluation:

Have students complete Worksheet 3.

Tundra

Trait or Adaptation	Possible Value	Example Of Organism With This Trait
thick fur	helps animal stay warm by reducing heat loss	arctic fox, muskoxen

EXPERIMENT 1.
SIZE AND HEAT

1. Which do you think loses heat (or gets cold) faster, a large object or a small one? (Write down your answer.) State your guess as an hypothesis.

2. You can find out if your hypothesis is correct by running a test. Fill a large and a small pail with warm water. Measure the temperature of the water in each pail and write it down.

Starting Water Temperature in Large Pail_____
Starting Water Temperature in Small Pail_____

3. Place both pails outside or in a cold place for 15 minutes. Then take another measurement of the water temperature in each pail. Write these measurements down.

Ending Water Temperature in Large Pail_____
Ending Water Temperature in Small Pail_____

4. Subtract the ending temperature from the starting temperature and record your answers.

Starting Temperature minus Ending Temperature in Large Pail = _______

Starting Temperature minus Ending Temperature in Small Pail = _______

Which one cooled down more? Which loses heat faster, a large object or a small one? Did you predict the correct answer?

5. Based on what you found out about the relationship between cooling and the size of objects, do you think that animals that live in tundra environments should be larger or smaller than animals living in warm environments?

6. Compare the sizes of the Arctic Fox and Kit Fox, Antelope Ground Squirrel and Arctic Ground Squirrel, Lemming and Jumping Mouse, Snowy Owl and Great Horned Owl. Which animal in each of these pairs is largest--the one living in tundra or the one that lives in a warm environment? Which do you predict would be larger? The moose in Wyoming, or moose in Alaska. Try to find out if you are correct.

EXPERIMENT 2.
LONG EARS AND HEAT

1. Which do you think keeps your hands warmer--gloves (with separate places for each finger) or mittens? State your answer as an hypothesis.

2. You can discover which is warmer by running a test. First take a pair of rubber gloves. Use rubber bands to close off the five finger compartments in one of the gloves. Be sure the rubber band is tight. This will be called the No Finger Glove. The other glove will be called the Normal glove.

Get a pail of water and measure the temperature of the water. Write this measurement down.

Starting Temperature of the Water_______.

Now measure 1 cup of water and pour this into the NoFinger glove. Close the top of the glove with another rubberband. Be sure to close it tightly so it won't leak.

Measure another cup of water and pour this into the Normal glove (which still has finger compartments). Close the top of this glove with another rubberband. Again, be sure to close it tightly so it won't leak.

Place both gloves outside or in a cold place, near each other, but not touching. Wait 15 minutes, then bring them both inside. Pour the water in the No Fingers Glove into 1 cup and the water in the Normal Glove into another cup. Measure the temperature of the water in both cups. Record your answer:

Ending Temperature of water from No Finger Glove________

Ending Temperature of water from Normal Glove_______

In which one did the water get colder?
How would you explain this difference? Next time its cold and you go outside, will you wear mittens or gloves to keep your hands warm?

Now think about animals that live in the arctic. The blood in their bodies is like the water in the gloves. Their toes, ears, and tail are like the fingers in a glove. Considering what you know about gloves and water temperature, which animal do you think would stay warmer in the arctic--one with long ears, toes, and tail, or one with short ears, toes, and tail?

Compare the ears of the Arctic Fox to those of the Kit Fox, and the ears of the Tundra Hare to those of the Desert Jackrabbit (shown on the Adaptation Cards). Can you give a possible reason for the differences you observe?

EXPERIMENT 3.
DARK COLORS AND HEAT

1. Which do you think would be a warmer coat--a black one or a white one? State your answer as a hypothesis that you could test.

2. This experiment will help you test your hypothesis. You need 2 tin cans of the same size--one painted black and one painted white. Get a pail of warm water and measure the temperature of the water. Record this:

Starting Temperature of Water: ______

Now fill each of the cans with water. Place both cans outside in bright, direct sunlight, or underneath a bright grow-light.

3. Wait about 15 minutes. Then, retrieve the 2 cans. Measure and write down the temperature of the water in each can: (If there is no difference, replace them outside and wait another 15 minutes.)

Ending Water Temperature in Black Can________
Ending Water Temperature in White Can________

4. Based on this experiment, can you accept or reject your hypothesis? Would a black or white coat be warmer?

5. Based on the results of this experiment, what color of coat do you think tundra animals should have in order to stay warm?

6. Think carefully about the insects, plants, and animals of alpine and lowland tundra. Are most of them the color you predicted? Why do you think most of the insects that occur in tundra regions are darker than insects that live in warmer environments? Why do you think most of the birds and mammals are not darker than animals that live inwarmer environments?

EXPERIMENT 4.
LIGHT COLORS AND HEAT

1. Which do you think would be a warmer coat--a black one or a white one? State your answer as an hypothesis that you could test.

2. This experiment will help you test your hypothesis. You need 2 tin cans of the same size--one painted black and one painted white. Get a pail of warm water and measure the temperature of the water. Record this:

Starting Temperature of Water: ________

Now fill each of the cans with water. Place both cans outside in a dark or shaded place.

3. Wait about 15 minutes. Then, retrieve the 2 cans. Measure and write down the temperature of the water in each can. (If there is no difference, replace them outside and wait another 15 minutes.)

Ending Water Temperature in Black Can________
Ending Water Temperature in White Can________

4. Based on this experiment, can you accept or reject your hypothesis? Would a black or white coat be warmer?

5. Based on the results of this experiment, what color of coat do you think tundra animals should have in order to stay warm?

6. Think carefully about the insects, plants, and animals of alpine and lowland tundra. Are most of them the color you predicted? Why do you think most tundra insects are darker than insects that live in warmer environments, while many of the birds and mammals that live in tundra regions year-round are white?

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HUMAN ADAPTABILITY....................................SOCIAL STUDIES / SCIENCE

....Indoors

OBJECTIVES: Students will recognize that humans cope with their environments by using tools and learning.
SKILLS: reading, comparing, inferring.
MATERIALS: Blackboard, chalk, reference materials about people living in the arctic.
PROCEDURE:
1. REVIEW THE PROBLEMS FACING LIVING THINGS IN A TUNDRA ENVIRONMENT. Write on the blackboard "Problems of Living in the Tundra" as the heading of a column. Ask students to list some of the problems faced by organisms that live in tundra environments. With prompting, students should be able to list Cold Temperatures, Long Winters with Little Food, Short Growing Seasons, and Wind. List these on the board.

2. REVIEW PLANT AND ANIMAL ADAPTATIONS FOR TUNDRA LIFE. Write "Animal and Plant Adaptations to the Tundra" as the heading of a second column to the right of the first. Ask students how tundra organisms are able to survive these problems. Students should be able to describe some of the traits, or adaptations, of tundra organisms which allow them to tolerate the "problems." List the adaptations named under the second column heading next to the related "problem." (If students can not describe some of the adaptations of tundra organisms, hand out the adaptation cards that show tundra animals and plants. Ask students to read the cards and then name some of the traits that help organisms survive in the tundra.)

3. DISCUSS WAYS HUMANS COPE WITH LIFE IN THE TUNDRA: Write a third column heading on the blackboard: "Human Methods of Surviving in Tundra." Then ask students to list specific ways that humans deal with the same problems that other tundra organisms must face. (E.g., Problem: Cold--people wear coats, build warm houses, use fire, or migrate (by going to Hawaii or the Lower 48); Long Winters with Little Food--people store food from summer; bring food in from elsewhere, or go elsewhere to find food.)
OPTIONAL: Have students use reference materials (books, encyclopedias, etc.) to learn how humans survive in tundra environments around the world.
4. DISCUSS THE SIMILARITIES AND DIFFERENCES BETWEEN ANIMAL AND PLANT ADAPTATIONS, AND HUMAN METHODS OF SURVIVAL IN TUNDRA. Students are likely to see the similarities between the ways other living things are adapted to the tundra and the ways humans survive. However, it is also important that students recognize the differences.

Animal and plant adaptations are genetically determined--meaning that tundra organisms do not choose, or decide, to grow thick fur for winter, or migrate, or grow large, or turn white. Adaptations are genetic traits, just like the colors of student eyes and hair, or student height, foot size, etc.

In contrast, most of the human methods of surviving in tundra environments are matters of choice. A person decides whether to "migrate" or stay through winter; whether to wear warm coats or stay in a warm house; whether to gather and store extra food during summer, have extra food shipped in from elsewhere, or go elsewhere to find food.

Encourage students to discover and understand this contrast by asking them whether or not an arctic fox (for example) could decide to migrate south. Could a plover decide to store food, grow a thick coat of warm feathers, and stay through the winter instead of migrating? If you planted the seed of a cushion plant from the tundra in a place with no wind, would it grow tall? Could a caribou "adapt" to a hot, dry desert environment? (If students have difficulty grasping that these adaptations are not decisions made by the plants and animals, ask them whether they could decide to grow a fur coat, or turn white in winter. They will soon realize that an animal or plant could not do so either.)

What about the methods people use to survive? Could an Inuit Native move to the desert and survive? Or, could someone from the tropics survive in the arctic? How? (By learning human methods of dealing with that environment.) Discuss the implications of this difference. Could tundra plants and animals survive if the tundra environment was somehow changed?

NOTE: Races of humans that have lived in a particular environment for thousands of years also have genetic adaptations to their environments. For example, the relatively small stature and build of arctic people are adaptations for surviving in cold and with less food during the long winters and food shortages typical of the north. Twilight vision (and associated color blindness) is more common in races of arctic people than in races of people who live at lower latitudes. This represents an adaptation for use of the long twilight periods that occur at high latitudes. Races of people native to tropical climates have physiological adaptations for resisting some of the diseases of their environment.

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Tundra Adaptations.......Language Arts

OBJECTIVES: Students will be able to identify some of the adaptations of tundra animals and plants.

SKILLS: reading comprehension

MATERIALS: Tundra Adaptations (pages 37-44)

PROCEDURE:
Have students read the descriptions of tundra adaptations (from the background section). You may have each student read all of them, or assign separate ones to individuals who then report what they read to the class. Have students complete the Reading Comprehension Worksheet for each of the close-ups they read. This can be used to evaluate their understanding of the material.

FREEZE-DRIED PLANTS..Science / Math

OBJECTIVES: Students will recognize that organisms that live in cold environments have adaptations to withstand cold.
SKILLS: observing, comparing, inferring
MATERIALS: a stem with fresh leaves of a cranberry plant (or other tundra plant with thick, waxy evergreen leaves) and a stem with fresh leaves of a houseplant such as a philodendron or coleus, freezer and a fan, Optional: thermometer, several jars, water, vinegar, sugar, antifreeze, a blackfish
PROCEDURE:
1. STUDENTS COMPARE THE LEAVES. Do not tell students what plants the leaves are from. Ask students to look carefully at the two types of leaves and write down any differences they see. Ask them to draw illustrations of each kind of leaf.
2. EXPOSE LEAVES TO COLD AND WIND. Tie one or more of each kind of leaf in front of a fan; turn the fan on high. Place one or more of each kind of leaf in a freezer. Have students observe the changes in the two kinds of leaves at 5 minute intervals, and record these with notes and illustrations.
3. DISCUSS THE RESULTS: Which kind of leaf was changed most by the cold and air movement (wind)? Were these changes good? Would the leaf still live after the changes occurred? (Place both leaves in water to find out, if there is any question.) Can students infer from the results which plant would survive best in a tundra environment? Why wouldn't the houseplant survive there? Why can the other plant tolerate the cold and wind more? (It has adaptations to resist cold and wind, including small leaves with a thick, waxy coating, a habit of growing flat along the ground (thus avoiding wind), and it produces antifreezes that prevent the fluid in its cells from freezing.
4. DEMONSTRATE THE EFFECTS OF FREEZING AND ANTIFREEZE: Fill and seal a plastic container with water. Explain to students that it represents a cell. Freeze it, and discuss the effects. (The expansion of the water as it freezes should break the container or pop the top.) Demonstrate the effects of antifreeze by freezing various solutions of water (mix separate solutions of plain water, and water with varying amounts of dissolved sugar, alcohol, or antifreeze. Be sure to label the various solutions.) Try to freeze the solutions. Measure and record the temperatures of each solution every 10 minutes until it freezes. Which mixture reached the lowest temperature before freezing? Does the amount of material in solution affect the freezing temperature?

Demonstrate the tolerance of a blackfish to freezing by placing a live one in a freezer for 15 minutes, then returning it to the water. [This remarkable fish can survive this treatment because it has antifreezes in its body, and it is able to breathe air through its esophagus (in addition to getting oxygen from water through its gills). Some have survived being frozen for 45 minutes--however parts of the fish must remain unfrozen in order for it to survive.]

Worksheet 3 a.
Reading Comprehension

Name__________________________________

Answer the following questions based on what you learned from reading about the adaptations of tundra animals. Circle the correct answer or answers to each question. More than one answer may be correct.

1. Some tundra animals avoid the most severe winter cold by: gestating hibernating adapting

2. Which of the following animals migrate? birds fish caribou

3. A staging area is: a place where birds nest a place where birds perform courtship displays
a place where birds gather before migrating

4. Some tundra plants and animals use snow to keep warm. True False

5. Many tundra insects do not have wings. True False

6. Tundra plants grow in low mats or cushions. This helps them
stay warm avoid the wind conserve water

7. How do insects, plants, and microscopic organisms survive winter without food?
by migrating by stopping all growth and activity by living off of stored energy

8. During the 7-8 months of winter, an arctic ground squirrel reduces its heart rate from 200-400 beats per minute to 7-10 beats per minute. True False

9. A brown bear may lose *30%* of its weight during winter. True False

10. Pikas live through winter by surviving off fat reserves by hibernating by living off of stored hay

11. Tundra birds and mammals have coats with 2 layers of feathers or fur. True False

12. A small animal loses less heat per unit of time than a large animal. True False

13. What kind of covering do tundra plants have that help them stay warm?
hair feathers wax oil dead leaves

14. Muskoxen can stay warm without moving even when the air temperature is minus 40° F (-40° C).
True False

15. Wood frogs can survive freezing temperatures because
they are dormant they freeze solid they make antifreezes

16. Some tundra insects can withstand temperatures of minus 60° C. True False

17. Animals that live in tundra environments tend to have longer appendages than those that live in warmer environments. True False.

18. Small animals may be at an advantage in tundra environments because they can survive with less food than a large animal of the same species. True False

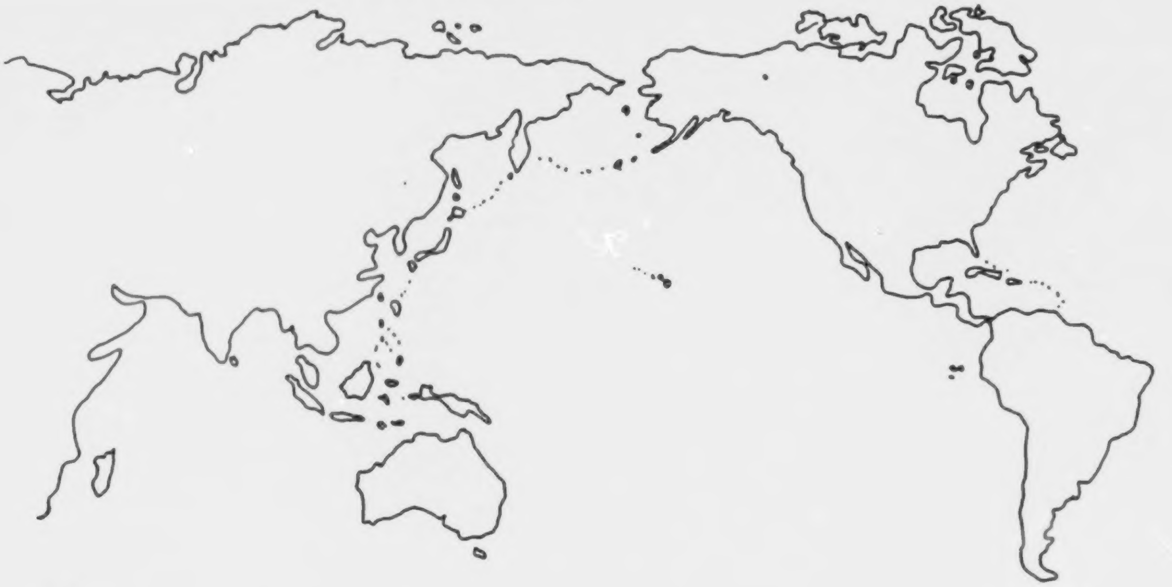
19. Dark coloration can help an animal stay warm on a winter day in the arctic tundra. True False

20. Some tundra plants are 200 to 300 years old. True False

Worksheet 3b. Bird Migration

Name________________________________

Use the information provided to find the migration routes of a few of the birds that nest in Alaska's tundra. Draw a line to show each route. Label each line with the number of the bird that travels that route. On the back of this paper, write down why you think migration is an adaptation for life in a tundra environment.



1. Whimbrels migrate south to spend the winter in coastal wetlands from southern California south to Chile.

2. Sanderlings migrate across the arctic, then down the east coast of North America, across the West Indies to the Atlantic coast of South America.

3. Black-bellied Plovers migrate to the central plains of Argentina for winter.

4. Emperor Geese winter in the sheltered coastal waters of the Aleutian Islands and Alaska Peninsula.

5. Arctic Terns migrate along the coast to spend the winter in Antartica.

6. Many Sandhill Cranes migrate to the coast of the Gulf of Mexico for winter.

7. Golden Plovers migrate to Hawaii and further south to the Polynesian Islands.

8. Lapland Longspurs migrate south through central Canada to winter in the central plains of the U.S.

9. Wheatears nest in alpine tundra. They migrate to wintering areas in Asia and North Africa.

10. Brant migrate north to molt in large lakes in the arctic tundra. Then, they migrate south to winter in lagoons along the coast of California and Mexico.

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Lesson 4.

Vocabulary:

commensalism, cycle, decomposition, detritus, food chain, food web, interdependence, mutualism, parasitism, peat, population, symbioses

Objectives:

Students will be able to describe some of the inter-relationships between the non-living environment and living things of tundra ecosystems, including food webs and symbioses.

Teacher Background:

Tundra ecosystems, like all others, are made up of all the non-living and living things present and the interactions among these. Tundra ecosystems are sometimes considered simple ecosystems because they are made up of relatively few species of plants, animals, and other living things (as compared to other kinds of ecosystems). Nevertheless, the non-living environment and living things in tundra ecosystems are tied together in complex ways. A summary of important points about the inter-connections within tundra ecosystems is provided below. More details are provided on the following pages.

1. FOOD CHAINS AND WEBS: Energy and minerals are exchanged between the non-living surroundings and living things via food chains and webs. However, the flow of these is considerably less than in other ecosystems because of the short growing season and cold temperatures.

Tundra producers make only one tenth to one third the food made by producers in forest ecosystems each year, and decomposition occurs very slowly. Tundra ecosystems have two important types of food chains, herbivore-based and detritivore-based. Only a small proportion of the food produced each year is consumed by herbivores, which are in turn eaten by carnivores. Instead, most of the material produced dies. Due to slow rates of decomposition, partially decayed material, called detritus, accumulates. The detritus is consumed by certain detritivores, which, in turn, are food for many tundra carnivores. Most detritivores feed on dead material from recently dead plants and animals, but some detritivore-based food chains exchange energy and minerals from peat--the detritus of producers that lived 1,000-12,000 years ago.

2. POPULATION CYCLES: Many populations of tundra animals fluctuate between high and low numbers. Some populations appear to fluctuate in a regular pattern, or cycle. Scientists do not yet understand all the reasons that such fluctuations occur, but plant-herbivore interactions, predator-prey interactions, behavior, genetics, and nutrient (mineral) recycling to the soil may be involved.

3. SYMBIOTIC ASSOCIATIONS: Many living things in tundra ecosystems interact with and depend upon other species in associations called symbioses. Three kinds of symbioses are recognized: mutualism, commensalism, and parasitism. Lichens, pollination, and mycorrhizal associations are examples of mutualistic symbioses--associations from which both interacting species benefit. The dependence of scavenging foxes and ravens on predatory wolves and bears, and the association of nesting birds with species that give predator-alarm calls, are examples of commensalism--symbioses from which one species benefits and the other is unaffected. In parasitic symbioses, one species, the parasite, benefits, while the other, the host, is harmed. The relationship between warbleflies and caribou is an example of parastitism.

4. OTHER CONNECTIONS BETWEEN NON-LIVING AND LIVING SYSTEMS: Some connections between the non-living environment and living things are more easily observed in tundra ecosystems than in perhaps any others. Changes of a few inches in elevation, a few days worth of snow cover, or a few degrees in aspect cause striking differences in the species of plants and other organisms that can survive. In addition, all the variation in environment and living things can occur within a few square meters of tundra. Similarly, the influence of living things on the non-living environment is striking and easily observed. The effects of vegetation on soil temperatures is dramatically revealed by the melting of permafrost and drastic changes in soil that occur whenever plant cover is removed or disturbed. The importance of nutrient recycling is clearly revealed by the lush growth that occurs around owl and jaeger perches, around ground squirrel and arctic fox dens, and around bones and carcasses of dead animals.

TUNDRA FOOD CHAINS AND WEBS:

The non-living things in tundra ecosystems include air, water, soil, rocks, and energy. Energy and minerals (defined as elements and common compounds) make up both non-living and living things. As in all ecosystems, the energy and minerals from the non-living environment move among living things via food chains and webs, then return to the non-living environment. Simply stated, a FOOD CHAIN is the pathway of energy and minerals from the non-living surroundings through producers and consumers and back. A FOOD WEB is made up of all the interconnecting food chains in an ecosystem.

PRODUCERS are those organisms that convert (through photosynthesis) energy from sunlight and minerals from the air, water, and soil into food for other living things. Plants, algae, and lichens are all important producers in tundra ecosystems.

Tundra producers can only function for a few months each year due to lack of light (from darkness and/or snow cover), low light intensity, cold temperatures, and lack of moisture. Thus, tundra producers are like a bottleneck limiting the flow of energy and minerals through the ecosystem. Scientists measure the flow of energy and minerals by determining the weight of carbon that is changed into living material (or fixed) by producers each year. The dry weight of all new growth--leaves, roots, flowers, cells, etc. is used to estimate carbon fixation. On average, all tundra producers together fix only 200 gms of dry weight per year per square meter (range of 100-1000 gm/m2/yr). In comparison, producers in forests fix an average 2000 gms of dry weight per square meter per year (range 1060-3460 gm/m2/yr). In other words, tundra producers make only 1/10-1/3 as much food each year as producers in forest ecosystems. This may be part of the reason that few species of herbivores occur in tundra ecosystems, and why large herbivores (such as caribou and muskoxen) travel over large areas of tundra to find food.

CONSUMERS, those organisms that cannot make their own food, form all the other links in food chains. Consumers are divided into several sub-groups, or trophic levels, based upon the foods they eat; these categories are herbivores, carnivores, and detritivores. Omnivores are consumers that function at 2 or more trophic levels.

HERBIVORES are organisms that eat producers. Lemmings, caribou, and geese are the most noticeable and important herbivores in lowland tundra ecosystems. Voles, pika, marmots, Dall sheep, and mountain goats are the most obvious and important alpine tundra herbivores. Invertebrate animals, particularly insects, are also important herbivores in some tundra environments. Bumblebees, moths, butterflies, aphids, and sawflies are examples of invertebrate herbivores.

Wolves, wolverines, arctic foxes, weasels, jaegers, gyrfalcons, golden eagles, and snowy and short-eared owls are conspicuous and important CARNIVORES of tundra ecosystems. These animals prey on the abundant vertebrate herbivores of tundra. Many kinds of small, insect-eating shorebirds are important carnivores in tundra ecosystems, despite the scarcity of insect herbivores (the reasons for this are discussed below). Relatively few insect-eating invertebrates occur in tundra ecosystems, but some predatory craneflies, spiders, and ground and rove beetles occur.

Most tundra consumers eat a variety of foods depending on what they can find, because food is often scarce. Typical herbivores such as arctic ground squirrels sometimes eat bird eggs, and caribou, which eat mainly plants and lichens, have been observed eating bird eggs and even lemmings. However, some tundra animals function at all 3 trophic levels (herbivore, carnivore, and detritivore.) They are called OMNIVORES. A brown bear is probably the best example of an omnivore; ground squirrels, carrion, and plant roots and berries, and (sometimes) caribou calves are all important parts of their diet in tundra ecosystems.

DETRITIVORES, consumers of dead organisms, are often overlooked, but are extremely important in all ecosystems. Detritivores perform the opposite task of producers by returning minerals and energy locked in dead (formerly living) things to the non-living surroundings. Without detritivores, producers would soon run out of the minerals they need to make food. Important tundra detritivores include: enchytraeid worms, springtails, mites, the larvae of many kinds of flies, nematodes, certain fungi, and microscopic organisms, including bacteria and protozoans.

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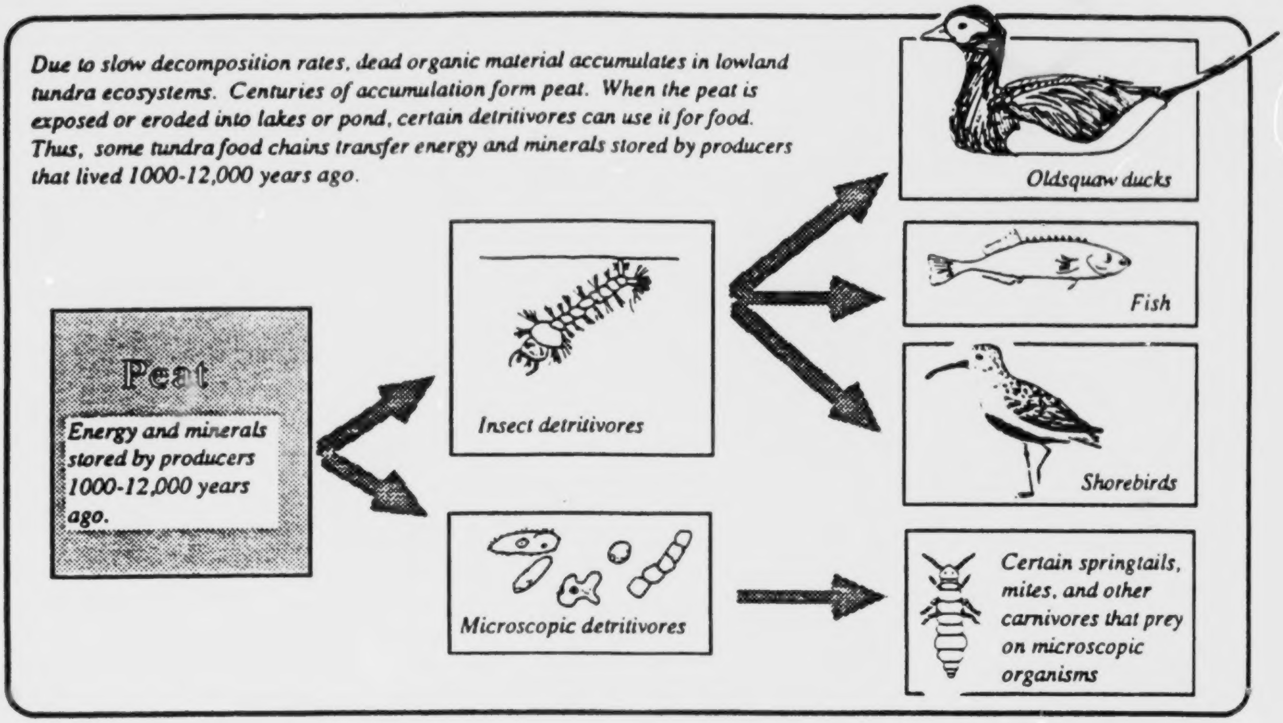

Oldsquaw ducks
Fish
Peat
Energy and minerals stored by producers 1000-12,000 years ago.
Insect detritivores
Shorebirds
Microscopic detritivores
Certain springtails, mites, and other carnivores that prey on microscopic organisms

Due to slow decomposition rates, dead organic material accumulates in lowland tundra ecosystems. Centuries of accumulation form peat. When the peat is exposed or eroded into lakes or pond, certain detritivores can use it for food. Thus, some tundra food chains transfer energy and minerals stored by producers that lived 1000-12,000 years ago.

Despite the abundance and variety of detritivores in tundra ecosystems, they represent a second bottleneck in the flow of energy and minerals. Most detritivores can only function in the top few inches of tundra soil (the top 2 in (5 cm) in the arctic) and only during a few short months each year because of the cold temperatures and (on some sites) the wet, acidic soils. The weight of all the dead material broken down by tundra detritivores is slightly less than the weight of new material made by producers each year. As a result, dead, partially decayed material, called DETRITUS, slowly accumulates in tundra ecosystems. In alpine tundra, wind and water erosion carry away much of the excess. But in flat areas of lowland tundra, particularly in the arctic, centuries of accumulation have created thick layers of detritus, called peat. A lot of energy and minerals are locked up in this peat layer.

At each link in every food chain, some energy is returned to the environment as heat and is lost to the ecosystem. It can not be reused. Because energy is not recycled, all ecosystems must have a constant resupply of energy from the sun, and this must be continually converted into food by producers. In contrast, minerals are recycled. Those that become part of a producer or consumer are passed along through food chains, until they are returned to the non-living surroundings where they are available for re-use by producers. Because of slow decomposition rates in tundra ecosystems, much of the nitrogen, phosphorus, and calcium that could be reused by producers is instead tied up in the accumulated detritus and is not available. As a result, the growth and production of many tundra producers is limited by lack of these minerals.

DETRITUS FOOD CHAINS--Despite the low productivity of living producers in tundra ecosystems, a surprising variety of consumers, particularly carnivores, flourish. This occurs because many tundra food chains are based not on living producers, but instead on dead organic material and, in the case of some food chains in tundra ponds and lakes, on peat. Detritivores break down waste materials and return energy and minerals to the non-living surroundings, but some of the food (energy and minerals) they consume is incorporated into their bodies. Many carnivores, including certain insects, ducks, shorebirds, and fish get the energy and minerals they need by feeding on detritivores. The energy and minerals in accumulated organic material thus forms the base of some arctic tundra food chains. Essentially, the consumers in detritivore-based food chains live off energy and minerals stored by tundra producers in past years. The consumers in peat-based food chains are actually supported by producers that lived 1,000 to 12,000 years ago!

POPULATION CYCLES:

Populations of many tundra animals, including lemmings, voles, redpolls, ptarmigan, and perhaps caribou, repeatedly fluctuate between high and very low levels. Population changes that occur repeatedly, and on a regular schedule are called "population cycles." This phenomenon is fascinating and puzzling to scientists. The population changes of brown lemmings in arctic tundra have been examined more closely than those of any other animal.

Brown lemmings occur at low densities [0.1-0.2 lemmings / acre (0.4 ha)] in many years, but in some summers, they become much more abundant [40-100 lemmings / acre (0.4 ha)]. The change from low numbers to high occurs in just 1-2 years, and the crash from high to low in just one summer. Near Barrow, the peaks in lemming numbers seem to occur every 3-6 years. In other areas, there is no recognizable pattern.

Scientists first thought that lemming populations cycled as a result of predators. During years when lemming numbers are high, resident predators such as weasels and foxes raise more young, and thus take more lemmings than in other years. Predators that move over vast areas of tundra, such as snowy owls and jaegers, concentrate in areas where lemming populations are high. These predators are only able to nest successfully if lemmings are fairly abundant, and they raise more young when lemmings are numerous. Thus, many more lemmings are killed and eaten by predators during the population high. Predation, especially by weasels, may reduce lemming numbers when their populations are at low levels. However, scientists have found that all the predators and their young could not eat enough lemmings to cause the sudden crash in lemming numbers that occurs after a population high. Also, the low breeding success of lemmings after a population crash cannot be explained as an effect of predation. Thus, scientists agree that while predation can affect lemming populations, it is not the main cause of the lemming population cycles. (However, the rise and fall of predator numbers and populations is clearly a response to changes in lemming populations.)

The main cause of lemming population cycles is still debated. The effects of lemmings on the availability of minerals to plants has been suggested as one possible cause of population cycles. The roots of most plants penetrate only the top few inches of tundra soil due to underlying permafrost. Growing plants soon deplete the minerals in this shallow layer of soil. Tundra plants conserve minerals in their roots from year to year, but lose minerals when herbivores eat their leaves and roots. According to the mineral-cycling hypothesis, most of the minerals are transferred through food chains to lemmings and their consumers during lemming population highs. Lacking mineral reserves, the plants begin to produce leaves that contain fewer minerals. Lemmings need a good supply of calcium, phosphorus, and nitrogen to reproduce. If the plants they eat contain few of these minerals, the number of young produced could be reduced. Low reproduction, combined with intense predation, could cause a rapid population decline. A few years would be required for plants to restore their mineral reserves. But, once the minerals were again available, the plants should begin growing mineral-rich leaves and roots, and supply nutritious food for lemmings. The lemmings could then produce more young, and their populations would increase. This hypothesis, while interesting, has not been proven. Scientists who have tested it have found that cold summer weather can cause a greater drop in the mineral content of tundra plants than does grazing by a peak population of lemmings.

Stress from over-crowding may also be a factor. At very high population levels, lemmings may spend so much time fighting each other that they do not successfully raise young. Animals may also die from stress. Lower reproduction combined with higher death rates due to intense predation and stress could lead to a sudden population decline. Another hypothesis that has been advanced is that genetic factors governing lemming behavior contribute to the population cycle. At low population levels, lemmings that produce many litters may raise more young to breeding age. At high population levels, however, when food and space are scarce, lemmings that produce relatively few young, but provide these with exceptional care may be more successful. If reproductive behavior and litter size are genetically determined, and some evidence suggests they are, then changes in the genetic make-up of the lemming population, combined with predation, could cause the cycle.

Scientists have also found that when heavily browsed, some plants produce chemicals that are distasteful to lemmings. As lemming numbers grow, more and more of the available plants are browsed heavily, and may become inedible. Eventually there may be too few edible plants to go around. Undernourished lemmings produce fewer young, and are more likely to die from diseases, parasites, or the stress of overcrowding, in addition to starvation and predation. Thus, the production of distasteful chemicals by heavily browsed plants could also help account for lemming population declines.

Scientists still debate the relative importance of predators, mineral cycles, plant toxins, behavior, genetics, and other factors, such as weather. But most agree that dramatic changes in lemming populations result from a combination of interconnnections between lemmings and their environment. Undoubtedly, the population "cycles" of other animals are also caused by a combination of ecological factors.

SYMBIOSES:

In addition to interacting through food chains and webs, many living things interact with and depend upon each other in other ways. When two kinds of living things "live together" or depend upon one another in some way, their relationship is called a SYMBIOSIS, or symbiotic association.

In some kinds of symbioses, both interacting species benefit from the association. The most striking example of mutualism in tundra ecosystems is provided by lichens. Many people mistakenly think that the lichens which cover much of the ground in many tundra areas are plants. Lichens are actually a combination of two organisms, a fungus and an alga or cyanobacterium, that live in a mutualistic symbiosis. The algae, which are capable of photosynthesis, manufacture food for themselves and the fungi. The fungi provide a protective shell that protects the algae from being dried out by the wind. In some cases the fungi may also help the algae obtain nutrients from rocks, the soil, or rain water by giving off acidic fluids that break down these surfaces.

Another good example of mutualism that is found in tundra ecosystems is pollination. Many tundra plants, like sedges and cotton grass, depend on wind to carry their pollen. Plants that are less common, or can grow only in specific sites on the tundra, must rely on insects to ensure successful exchange of pollen with others of their species. About 90 percent of alpine and over 60 percent of arctic tundra flowers are insect pollinated. (However, most tundra plants have back-up methods of reproduction, so they can survive even without pollination.) Bumblebees are one of the most important pollinators found in tundra ecosystems, but many insects, including butterflies, moths, mosquitos, and other flies are also important pollinators of tundra plants. The pollinators benefit from this association because the plants supply them nectar and pollen for food.

Other examples of mutualism include the connections between berry plants and berry-eating animals that carry their seeds, between nitrogen-fixing bacteria and certain legumes, and between mycorrhizal fungi and certain plants. In the latter two examples, the former organism helps the plant obtain needed minerals, while the plants provide sugars for their symbionts.

The term "commensalism" is used to describe symbiotic associations from which one species benefits, while the other is unaffected. For example, arctic foxes scavenge food from the kills of polar bears, brown bears, and wolves. These larger predators are unaffected–essentially they don't miss the scraps--but the foxes benefit from the food that they could not obtain on their own. Another example of commensalism is the relationship between golden or black-bellied plovers and other smaller shorebirds. Plovers nest on high spots on the tundra--frost boils, pingos, and ridges. Both the male and female plovers guard their nest and are very watchful for possible predators. Plovers give a loud warning whistle to warn their mate on the nest to be alert whenever they spot a predator. Other smaller shorebirds have been found to nest near plovers and to react when the plovers give an alarm call. By nesting near a plover, these birds gain a sharp-eyed guard for their own nests.

In a third type of symbiosis, one species benefits while the other is harmed. One of the most striking examples of parasitism is the relationship between warbleflies and caribou. These parasitic flies lay their eggs on a caribou's coat. When the eggs hatch, the larvae burrow into the caribou's skin and feed on the caribou's body fluids. When the larvae are fully grown, they burrow out and drop to the ground, where they eventually metamorphose into adult warbleflies. The warblefly larvae benefit from the food and shelter provided by the caribou, but the caribou suffer. Caribou under attack by warbleflies spend less time feeding and ruminating, and more time moving to avoid the flies. Severe harrassment by flies may result in caribou entering winter in poor condition, and ultimately reduce their survival and reproductive success. Many kinds of parasites occur in tundra, including fungi and insects that parasitize plant roots and many microscopic organisms that cause animal and plant diseases.

Introductory Activity 4.

Objective:

Students will recognize some of the ways in which the living things in tundra ecosystems are interdependent.

Skills:

SCIENCE: comparing, inferring LANGUAGE ARTS: reading, oral communication

Materials:

Tundra Wildlife Cards (cut out and laminated), marking pens or crayons in several colors, a large square piece of butcher paper, masking tape.

Procedure:

SUMMARY: Students will use information on the tundra wildife cards to play a game in which the goal is to make a diagram showing the interconnections among the living things in a tundra ecosystem. Points are awarded for adding organisms to the diagram, and for finding food web or symbiotic connections.

1. PREPARATION: Cut out and laminate the Tundra Wildlife Cards; Unless you plan to do an alpine tundra web, sort out and set aside those cards showing animals that occur only in alpine tundra (pika, marmot, singing vole, mountain goat, Dall sheep, horned lark, water pipit). Tape the sheet of butcher paper on a wall or blackboard at a level that will allow students to draw anywhere on the paper (i.e. don't put it up so high that most students couldn't reach the top edge). Draw a large target on the paper. Label the bulls-eye: "Non-living environment". Label the surrounding rings as follows: innermost--"Producers", next outward-- "Herbivores", then "Carnivores", and finally "Detritivores or Decomposers".

2. PASS OUT THE TUNDRA WILDLIFE CARDS: Divide the class into groups of 3-6 students. Pass out 2 cards to each group. Retain the rest in a pile at the front of the room. Ask students to look at their cards and read the information provided to familiarize themselves with the pictured items.

3. REVIEW THE THREE KINDS OF ECOSYSTEM CONNECTIONS: Explain that the the cards (representing the living things of tundra) connect together in three ways: by food chain connections, by symbiotic connections, and by miscellaneous connections between living things and the non-living environment). Review the terms "food chain" and "symbiosis".

A food chain connection is any connection between an organism and the organisms it eats, or the organisms that eat it. For example, a caribou is connected to the plants and lichens it eats, and to the predators that eat it, including wolves, bears, and wolverines.

A symbiotic connection is any connection between two kinds of living things that involve something other than, or more than food. For example, a bee and a flower have a symbiotic connection because the bee carries pollen for the flower.

Question students to be sure they understand the two types of connections. Have each group read their cards and figure out 1 food chain connection and 1 symbiotic connection for each of the pictured organisms. (Each card lists the foods and predators of the pictured organism, and any known symbioses, so students do not need to guess, they only have to read.)

4. PLAY THE TUNDRA CONNECTIONS GAME: Explain that the class is going to play a game called "Tundra Connections". Each group may earn points in the game by helping complete a diagram of the connections among tundra organisms and their environment. The group with the most points at the end of the game, wins. Points are earned by adding cards (organisms or non-living things) to a diagram of the ecosystem, and by finding the food chain and symbiotic connections between the parts of the ecosystem. Each group will have several 1 minute turns to add a card and draw in any connections they can identify. In order to use their 1 minute effectively (get the most points) the team must work together. (The game will start out slowly, but as students add more cards, and understand how to play, it will begin to move quickly and become quite complicated.) Discuss the rules of the game with the class (see next page), then play the game for a set period of time.

5. DISCUSS THE COMPLETED DIAGRAM: Ask students to look carefully at the completed gameboard and try to figure out what it shows. (They should recognize that the gameboard shows many of the ways that the living things in the tundra are interconnected, and that altogether it represents a tundra ecosystem. Discuss the definition of an ecosystem (all the living and non-living parts of an ecosystem and their interconnections.) Ask students, so what? What does it matter that all the living things are interconnected?

What if something in the ecosystem changes–for example a particular insect or plant becomes extinct? Or, if the non-living environment were changed–for example, if the climate warmed? What would be affected? Have students examine one of these examples and trace the connections. Discuss the changes that might occur. Do students understand that any change in the non-living environment, or in a population of a particular living thing, will cause many other changes in the ecosystem?

Evaluation:

Have students write an essay describing the effects on the tundra ecosystem which they would predict if one of the following occurred:

A mosquito control program–application of a pesticide that kills mosquitos and other flies over a large area of tundra.

Warming of the climate caused by increased carbon dioxide in the environment.

Evaluate and discuss student answers. Did they consider food chain and symbiotic connections in making their predictions?

CONNECTION GAME RULES:

1) On their turn, the playing team has 1 minute to come up to the game board (the butcher paper target) and add 1 card and as many connections as they can find. Cards are added by taping them to the board. Connections are added by drawing lines between organisms hat are connected by food chain connections or symbioses. A food chain connection should be shown by drawing a red line, a symbiotic connection by drawing a blue line.

2) On a turn, the group may use 1 card from their hand, or discard a card from their hand and draw a new one from the top of the remaining pile or discard pile (in which the top card is face up.) and play it.

3. A card showing any living thing (other than a producer) may only be added to the board if the living thing connects with at least 1 other card of a living thing that is already on the board. Producers (organisms that make their own food) may be added with just their connection to the non-living environment since they use non-living things (air, water, sunlight, and minerals) to make food.

4. Points are awarded as follows:

1 point for adding a card to the board (connecting to the non-living environment).

1 point for each food chain connection

3 points for each symbiotic connection

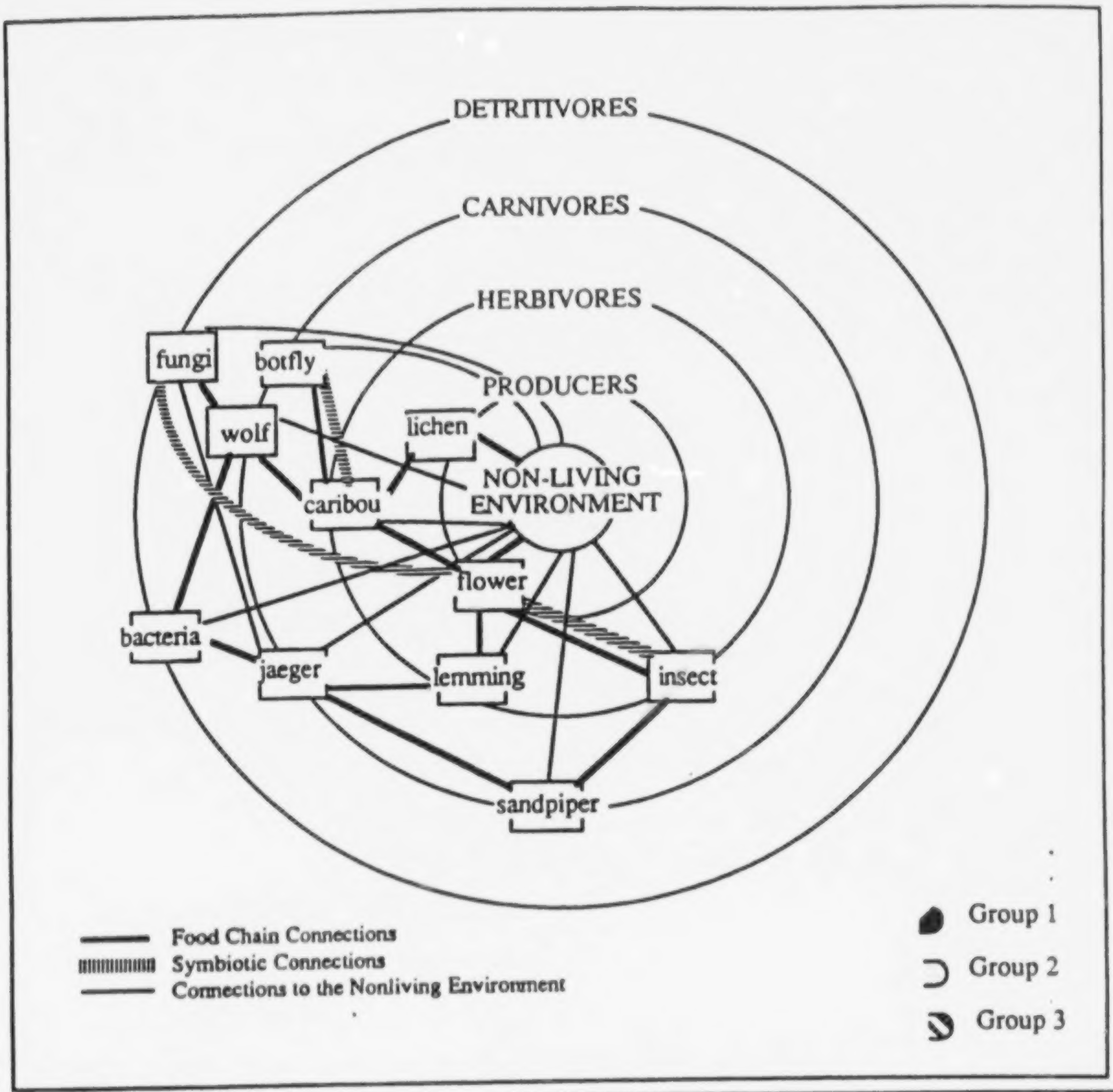
5. A team may add connections between the card they add to the board (they must add at least one in order to place the card), and may also add connections between cards that are already on the board. If a team cannot add a card, they may still add connections between cards already on the board.

6. To keep some semblance of order on the board, students must place their cards in the appropriate band--i.e. producers must go in the producer band, herbivores, carnivores, and detritivores in their respective bands. Omnivores, and those cards which fit in more than one category may be placed in any of the bands in which they fit.

7. To identify which group made each connection, each group should have a unique color of marker and use it to draw a small plug at each end of each connection they draw (See diagram).

9. The instructor or an appointee will keep the scores for each team.

10. Between turns, each group should be planning strategy. They should look for missed connections between cards on the board (so they can add these on their turn and earn points), read the cards in their hand and determine which one they'll play and what connections they'll add, and possibly assign individuals within the group to specific tasks (taping up their card, drawing in particular connections, looking for connections missed by other groups, or figuring out symbiotic connections, etc.)


DETRITIVORES
CARNIVORES
HERBIVORES
PRODUCERS
NON-LIVING ENVIRONMENT
fungi
botfly
wolf
lichen
caribou
flower
bacteria
jaeger
lemming
insect
sandpiper
Food Chain Connections
Symbiotic Connections
Connections to the Nonliving Environment
Group 1
Group 2
Group 3

EXAMPLE SCORECARD

	Group 1	Group 2	Group 3
Cards Added(1 pt each)			
Food Chain Connections (1 pt each)			
Symbiotic Connections (3 pts)			

OBJECTIVES: Students will recognize that tundra ecosystems are less productive than other ecosystems because of the relatively slow rates of production and decomposition.
SKILLS: observation, inferring, predicting
MATERIALS: several bean plant seeds, potting soil, water, egg cartons or small pots, 2 grow lights, dark area, and warm and cold sites.
PROCEDURE:
Summary: Students will expose plants, and dead organic material (fruit) to various regimes of light and heat to find out the effects of light levels and temperature on plant growth and on decomposition. The instructions below are written so that an individual or group of students can do the experiments.

LIGHT AND PLANT GROWTH

1. Why do plants need light?

2. Based on your answer above, how do you think that the amount of light a plant receives will affect its growth. Do you predict that it will grow slower, faster, or at the same rate if it receives less light?

The following experiment will help you find out if your prediction was correct.

3. Divide 2 egg cartons in half, then fill each half with potting soil. Place one bean seed in each of the egg sections. Lightly water, then cover the soil with plastic. Place two of the carton halves under growlight #1. Place the other two under growlight #2. You will now control the amount of light received by the plants. Leave growlight #1 on throughout your school day. Turn it on in the morning, and off before you go home from school. Turn growlight #2 on when you arrive at school, but turn it off at lunch. That way, the plants under growlight #2 will receive only half as much light as those under growlight #1.

4. For the next two weeks, carefully observe the results of your experiment. Draw a picture of the plants in each carton, and measure their heights every other day.

5. Based on the results of your experiment, do you think arctic tundra plants grow faster or slower than plants in enviroments further south? The number of herbivores that can live in a given area depends upon the amount of food produced by the plants in the area. Which area do you think would have more herbivores living in it, a square mile of land at a high latitude, or a square mile of land at a low latitude? Explain your answer.

PRODUCTION, DECOMPOSITION, AND TEMPERATURE

1. Do you think temperature affects plant growth or the decay of organic material? If you do, how do you think the two are related? Write down your answer.

The following experiment will help you figure out whether your idea is correct.

2. Divide 2 egg cartons in half, then fill each half with potting soil. Place one bean seed in each of the egg sections. Lightly water, then cover the soil with plastic. Place two of the carton halves in the sunlight in a warm spot. Place the other two in the sunlight close to a cold window, or on top of a pan of ice. (If you place them on a pan of ice, be sure to replace the ice daily.)

3. Place a piece of an apple or a piece of bread in each of two plastic containers. Add a teaspoon of water to each container. Put the lids on both containers, then place one in a warm spot, and the other in a cool spot, such as a refrigerator.

4. Observe both your experiments carefully over the next 2 weeks. Record your observations every other day.

5. Based on your experiment, how does temperature affect plant growth and decomposition?

6. From your observations, what can you infer about the rates of plant growth and decomposition in tundra environments? Do these processes occur faster or slower than in warmer environments?

7. How might the rate of plant growth affect the number of animals that live in a particular environment?

8. How might the rate of decomposition affect plant growth, and the number of animals living in a particular environment?

9. Based on your observations and inferences, can you explain why tundra environments support fewer animals than other environments?

Lemming Cycles..Math / Science
....Indoors / Outdoors

OBJECTIVES: Students will recognize that changes in animal populations are caused in part by the many interconnections between living things and their environment.

SKILLS: teamwork, inferring, predicting, counting, graphing

MATERIALS: Large group of students or 40 cards with one symbol printed on one side, and another printed on the back; paper and pencil or blackboard and chalk

PROCEDURE:

SUMMARY: Students will play a game in which the class represents various trophic groups in a tundra ecosystem, and through a simulation, will learn how many factors can affect animal populations.

Step 1. This game begins simply, and becomes more complex as additional factors are added. Explain that the class is going to build a simple model of a functioning tundra ecosystem. Ask students what they need first in order to build a tundra ecosystem. They should guess the non-living environment. If students name organisms, ask whether the animal could survive without anything else in the ecosystem--what would it eat? How would a plant make food if nothing else was present? Explain to students that the supply of energy from the sun is constant, but the minerals in the soil, water, and air are limited resources. Of these, the minerals in soil are the resource in shortest supply in the tundra--so the first group of students will represent soil minerals.

Ask students what the next building block of an ecosystem would be? They should guess producers. Ask the rest of the class to represent tundra plants. Ask the two teams to stand in lines, with their backs to each other. Explain that on each round of the game, members of each team have a choice between two gestures--arms folded, or hands on their shoulders. Have each player make a gesture. Explain that you will soon have the teams turn around. When this occurs, each plant player must try to catch a mineral player who is making the same gesture. A plant player can not catch a mineral player who is making a different gesture. Each plant must catch one mineral player in order to survive. Those plants who do not catch a mineral, die, return to the soil and become mineral players. Mineral players who are caught turn into plant players. Mineral players who are not caught remain minerals. Play a few rounds of this to see what happens to the plants and minerals. Assign 1 student to graph the changes in the plant population.

STEP 2. Ask students whether their model is a good representation of an ecosystem. They should recognize that their model needs some consumers. Assign one student to make a graph of the herbivore population. Divide the class in thirds and add a population of herbivores--for example, lemmings--to the model. Have the plant and minerals teams line up so their backs are towards each other. Then have the lemming team line up so their backs are towards the plants.

Ask the plant and minerals players to make one of the two gestures, then have the plants turn to face the minerals and again exchange the matched and unmatched players. These players must retain the gestures they made previously.

Have the lemmings make gestures and turn to face the plants. Plants that are matched by a lemming become lemming players. But, lemmings who do not find a plant match do not become plants; rather, they die and return to the soil as minerals--so they join the mineral team. Play a few rounds. The student who is making the graph should count the population after the entire round is complete (all teams have turned and matched).

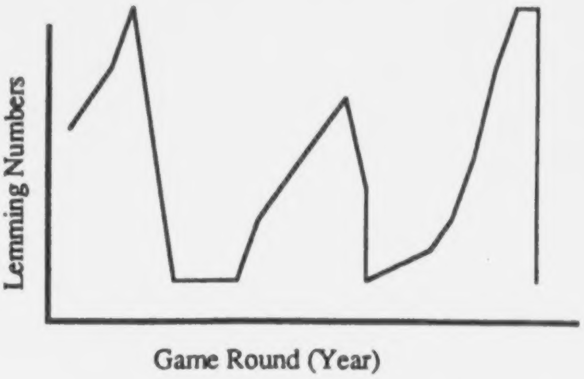
STEP 3. Repeat Step 2, but this time add a fourth team--predators. On each round, the plants and minerals match first and exchange, then the lemmings and plants, then the predators and lemmings. Play several rounds of this, then discuss the graphs that resulted and compare them to the previous graphs.

(continued on next page)

Alaska Wildlife Week Unit 6. Tundra. © 1988 ADF&G

STEP 4. Ask students whether they now think their ecosystem model is fairly complete. Encourage them to recognize that, in fact, detritivores are needed to decompose the dead organisms and return minerals to the soil. Explain that on the next round, to correct this problem, those plants and animals that don't find a match and die, should go to a separate "holding area", rather than returning to the soil as minerals. For accuracy, separate detritivore teams might be needed for plant and animal remains--but to simplify matters its best to use only one detritivore team. Explain to students that just as there are many factors influencing lemming numbers, many factors affect detritivore populations. But, in tundra areas at least, cold temperatures, and wet acidic soil severely limit the activities of most detritivores, so the amount of dead material available is more than the detritivores can decompose. For this reason, the most realistic way to add detritivores to the game is to add a team of 2 players whose only role in the game is to move players from the holding area to the minerals team. Detritivores may only move one player at a time, but they can be active throughout each round. Play several rounds and graph the results. Discuss with students how the slow rate of decomposition in tundra could affect the other living things in the ecosystem. How mightthe availability of minerals in the soil ultimately affect lemmings and their predators?

STEP 5. The model above will now illustrates some of the inter-relationships among predators, prey, their foods, and the non-living environment. However, even this fairly complicated model leaves out some potentially important connections. For example, scientists have recently determined that plants which are grazed heavily begin producing distasteful chemicals that repel lemmings. The effects of this interesting connection can be simulated by having each plant and the mineral it catches function as a pair--by standing next to each other. Each member of the pair must give a different gesture. If only one member of the pair is matched, the surviving one may (on the following round only--assuming it gets a mineral match) make a third gesture (hands clasped) indicating that it is distasteful or inedible and can't be matched.



STEP 6. As a follow-up to this game, have students read the background information on Population Cycles from this packet.

VARIATION: If you do not have a large class, you may simulate the game using cards. Make up 40 cards with one symbol (X) on one side, and another symbol (*) on the other side. Assign one student (or a team of students) to represent each of the following: minerals, plants, lemmings, and lemming predators. Give each of the students 10 cards. Students place the cards on the table, varying the symbols that face up. The game is then played the same as described above, except that players place their cards face up, then match and trade cards among teams instead of signaling and moving themselves among the teams. In Step 4, assign one player to be a detritivore. In Step 5, place surviving plant cards in a sideline pile during the lemming--plant exchange portion of the next round. Have one student count and graph the lemming population after each round.

Credit: This game was inspired by the activity "Oh Deer!" from Project Wild.

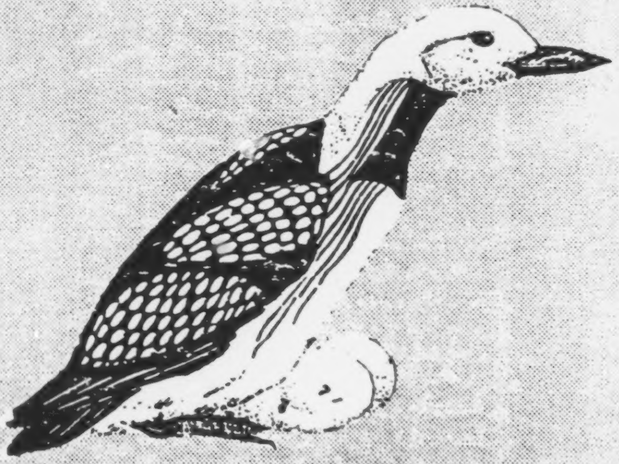
Food Chain Relay...Outdoors / Indoors ....Physical Education / Science

OBJECTIVES: Students will become more familiar with tundra animals and food chain connections while practicing physical education skills.
SKILLS: running or other physical education skill; identification of living things and food chain connections
MATERIALS: Tundra wildlife cards, large room or playing area.
PROCEDURE:

1. Preparation: Divide the class into equal-sized groups of 5-6 students. Draw a starting line. Lay the tundra wildlife cards out on one side of a large playing area. Explain that the objective is for each team to attempt to put together a tundra food chain that includes the non-living environment, a producer, herbivore, carnivore, and detritivore.
2. Each student in each team must run (or skip, hop, walk) to the other end of the playing area and get one wildlife card to bring back to their group. The next team player can not leave until the previous player has returned with a card. The team may keep the card if it fits into a food chain, or is symbiotic with an organism on another card the team already holds. However, if the organism does not fit into their food chain, and is not symbiotic, it must be returned to the card pile by the next runner.
3. Whenever a team has a complete food chain, they yell out "Food Chain." If the food chain is complete and correct, their team wins 10 points plus 5 points for each symbiotic match they have. All the teams then return their cards to the card pile, and another round is begun.
4. If the food chain is incomplete or incorrect, the team loses 5 points, and the game resumes where it was left off. (To make the game more difficult, remove the cards in the winning food chain set constructed in each round.)

Food Chain Connections..... Indoors .... Science

OBJECTIVES: Students will become more familiar with the living things in tundra ecosystems and their interconnections.
SKILLS: observation, inferring
MATERIALS: Tundra Wildlife Cards, Tundra Posters
PROCEDURE:
Students try to identify all the interconnections among the organisms shown in one of the Tundra Posters. They may work individually or in groups to identify the pictured organisms and their interconnections.



Worksheet 4. Tundra Connections

Name________________________________

Read the following paragraph, then answer the questions below.

Lemmings are small mammals that live in both alpine and lowland tundra environments. They feed on a variety of plants, including willows, sedges, grasses, and herbs. Green shoots, buds, seeds, and berries are all part of a lemming's diet. They also eat lichens, and occasionally other foods such as insects or bird eggs. Seeds of some plants often become entangled in the long fur of lemmings. Lemmings tunnel through dry soil in summer. Their tunnels help air and water permeate the soil, and make it easier for plant roots and fungal hyphae to penetrate the soil. Lemmings have many predators, including arctic foxes, weasels, long-tailed and pomarine jaegers, short-eared and snowy owls, and glaucous gulls. In winter, lemmings dig tunnels under the snow. Soft, thick snow protects lemmings from the severest cold and wind of the tundra, thus helping them survive the harsh winter. Shallow, crusty snow provides little insulation, however. Lemmings also build nests of mosses and grass leaves, and sometimes use ptarmigan feathers or muskox hair. A variety of small organisms live in and on lemmings, including small worms, fleas, lice, and various bacteria. Biting insects, such as mosquitos and certain flies, feed on the blood of lemmings and other mammals. A variety of fungi and bacteria live on lemming droppings. These detritivores decompose the droppings and return minerals to the soil, where they can be re-used by plants. In fact, lemmings play an important role in the mineral cycle. Dried, standing dead leaves of plants decay very slowly, because most tundra detritivores can only survive in the moist and sheltered soil environment. In years when lemming populations are high, lemmings eat or tear up the moss and grass cover over fairly large areas of tundra. Lemming droppings and the torn up dead leaves on the wet soil surface are available to thelarge number of detritivores in the soil. After these decomposers work, many minerals, formerly stored in the dead leaves, are returned to the soil where plants can reuse them. Thus, tundra plants can actually grow faster if lemmings are present.

Describe 4 connections between lemmings and the non-living environment. (Think of the ways lemmings affect or are affected by the non-living environment.)

1.____

2.____

3.____

4.____

Complete the following food chains. Do not use any kind of organism more than once.

__________ __________ lemming __________ __________

__________ __________ lemming __________

________ ________ ________ lemming ________ ________

Give one example of each of the following types of symbioses involving lemmings and other kinds of organisms. Specify how each organism is affected in each association (which one benefits and how).

Mutualism ____

Commensalism ____

Parastism ____

Lesson 5

Vocabulary:

development, fragile, permafrost, productivity, resilient,

Objectives:

Students will recognize some of the problems of use and conservation of tundra wildlife and tundra ecosystems.

Teacher Background:

TUNDRA ECOSYSTEMS: FRAGILE OR RESILIENT? As human populations in tundra regions increase, and as our desires, abilities, and needs to develop resources found in tundra regions increase, humans are changing the tundra. Many scientists are concerned that we may inadvertently, and irreversibly damage tundra ecosystems and wildlife populations. In comparison to most other ecosystems on earth, tundra ecosystems appear relatively simple. Fewer species of plants, animals, and other living things are present, so there are relatively fewer ecological connections. This lack of complexity has led some scientists to conclude that tundra ecosystems are more fragile than other ecosystems, but it has also led other scientists to conclude that tundra ecosystems are more resilient.

Those who consider the tundra to be fragile point out that because there are few interconnections, changes in any single plant or animal population are likely to affect the entire ecosystem. These scientists argue that human activities that affect one tundra species are likely to indirectly affect many other species, just as, for example, natural changes in lemming numbers result in striking changes in populations of foxes, weasels, owls, and jaegers.

Scientists who consider tundra ecosystems more resilient than other ecosystems point to the wide oscillations in animal numbers that occur naturally, the ability of key tundra wildlife, such as lemmings, to reproduce rapidly, and the continued abundance of many tundra birds despite frequent years of nesting failure. These scientists think that since radical changes in animal and plant populations and production occur regularly, tundra ecosystems have a better built-in ability to absorb changes and continue intact than do other ecosystems.

Regardless of tundra's relative fragility or resiliency, however, most scientists agree that we must be cautious in our use and development of tundra resources, because the tundra is different from other ecosystems. Low productivity, the ease of overexploitation of animals, slow decomposition rates, the instability of permafrost ground, and the sensitivity of lichens to air pollution are points which are often raised.

LOW PRODUCTIVITY: As mentioned in previous sections, tundra plants and lichens grow much more slowly than those in other ecosystems, primarily because the growing season is so short, but also due to the low angle of the sun and cool temperatures, both of which affect the rate at which photosynthesis can occur. Most tundra plants of any size are decades or, in some cases, centuries old, and most lichens are also quite old. When plants and lichens are removed by humans, or overgrazed by domestic animals or concentrations of wild animals, decades may be required for plants to become re-established on a site.

Most tundra wildlife also grow and reproduce slowly. For example, brown bears that live on the tundra of the Brook's Range do not breed until they are 8 years old, and then give birth to 2 young only every 4 years. In contrast, brown bears that live in the more productive coastal forests of southcoastal Alaska begin breeding when 4 years old, and have 2-3 young every 3 years. Although certain tundra bird species lay more eggs than related species in milder environments, their overall productivity is lower because they can nest only once each year, complete nesting failures are common, and they likely suffer higher mortality during their long-distance migrations. Some of the large fish found in some tundra ponds and lakes are now known to be 40 years old or more. In contrast, the same kinds of fish in other more productive environments may grow to similar weights in 20 years. Tundra fish such as the

lake trout may reproducing until 10 years old, and then produce fewer eggs than fish in other environments. Populations of animals with slow growth and reproductive rates increase slowly, may decline rapidly if mortality (the number of animals that die) increases, and can only regrow slowly. Small increases in the number of animals that die can thus cause a long-lasting decrease in a population of tundra animals.

Evidence of the vulnerability of tundra wildlife populations is provided by fairly recent declines in certain populations of Alaskan wildlife as a result of overexploitation by humans. Muskoxen were completely extirpated from Alaska during the 1850's, and were it not for surviving populations in Greenland and Canada, the species would have become extinct. The western arctic caribou herd declined from 242,000 in 1970 to less than 75,000 in 1976. The number of wolves living on lands along the Dalton Highway (which parallels the Alaska oil pipeline) was greatly reduced during the 1970's. All of these wildlife population declines are thought to have occurred, at least in part, because too many animals were killed by humans. Humans kill animals for food, furs, sport, protection of life and property, and accidentally (by vehicles on highways, for example). Any population of wildlife will decline if more animals die than are born. Because most tundra animals are slow to mature, and produce few young relative to similar animals in milder environments, the harvest or killing of a relatively small number can cause a population decline (of some species). Tundra wildlife are also more easily overharvested because of the lack of cover--hunters can see them from long distances away.

SLOW DECOMPOSITION: Decomposition, or the breakdown of organic materials, occurs very slowly in tundra environments due to cold temperatures and the short season during which detritivores can be active. Chemical breakdown and weathering of inorganic materials also occur relatively slowly due to the extreme cold and low precipitation of most tundra regions. Consequently, litter and human wastes disposed of in tundra regions remain unchanged for decades and even centuries. Already many tundra areas are littered by disposable diapers, bags of human waste, abandoned oil drums, cans, plastics, and other materials. Unless this material is burned or physically removed by people, it will remain in place, and intact, for centuries.

Accumulated pollutants have more toxic effects than those that are widely dispersed. Because of the slow decomposition rates in tundra environments, air and water-borne pollutants often accumulate. Some tundra organisms, particularly fruticose lichens, are very sensitive to air pollution created by burning fossil fuels. Use of combustion engines in cars, planes, and snowmobiles, and burning of fossil fuels for heat or other uses creates air pollution. Although winds help disperse air pollution in some regions, temperature inversions can result in high concentrations of these pollutants. Additionally, winds may carry pollutants from industrial areas long distances to wilderness areas. Recently, scientists have discovered that some air pollution occurring in Alaskan arctic tundra may have originated in industrial areas of the Soviet Union and Europe.

PERMAFROST: Most of the tundra in northern and northwestern Alaska is underlain by permafrost and/or ice. Disturbance or removal of tundra vegetation reduces the vegetative insulation of the soil and results in permafrost melting. When permafrost in wet soil melts, the ground slumps, creating a depression. This depression fills with water during summer. The water absorbs heat from sunlight, which further melts underlying permafrost. In winter, the collectedwater freezes and expands. As it does so, it pushes surrounding soil out and up. Through repeated freezing and thawing and the eroding effects of wind and water the depression grows larger each year. Centuries of accumulation of organic matter may eventually insulate the soil again allowing permafrost to re-develop; only then will the tundra return to its pre-disturbance condition. Because of this long chain of events triggered by disturbance of tundra vegetation, human activities such as driving three-wheelers, snowmobiles, trucks, and particularly larger vehicles over the tundra create very long-lasting and easily visible scars on the land.

In recent years, engineers have prevented melting of tundra permafrost by leaving tundra vegetation intact and piling several feet of gravel on top of it to provide insulation below road surfaces and buildings. This method prevents permafrost from melting, but causes other changes in the tundra. Gravel road beds and building pads are similar to gravel river beds. They are sometimes used by animals that prefer dry tundra. However, few tundra plants can grow on bare gravel, so these pads will remain bare for decades.

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These bare gravel sites do not provide the same camouflage or food supplies that natural dry tundra sites do. Additionally, gravel road beds and building pads interfere with the natural flow of water across the tundra. Water usually backs up along the upstream side of the pads. This floods formerly dry or moist sites, melts permafrost, and creates new depressions and ponds, thus changing a much larger area of tundra than the roads or pads themselves cover. Dust that blows off pads and roads also changes snowmelt patterns in surrounding areas. Finally, the huge amounts of gravel needed to build the roads and pads must be excavated from river beds and gravel banks. The extraction of gravel can affect water flow, turbidity, and other physical characteristics of rivers, thus upsetting fish migration and destroying overwintering and spawning habitat of fish. It also removes riparian (streamside) habitat that is important for muskoxen, caribou, ground squirrels, ptarmigan and other birds, as well as other kinds of living things.

VASTNESS AND VULNERABILITY:

To many people the vastness of lowland tundra is part of its beauty and wilderness value. Others feel that because the tundra covers such large areas, human activities do not have a significant impact on the tundra ecosystem. To an extent, both viewpoints are correct. Most tundra wildlife are forced to use large areas to obtain adequate food. The great caribou herds and wolves, their predators, wander over thousands of square miles. Tundra brown bears have home ranges of 100-400 square miles. Even fairly small birds like golden plovers defend territories measured in acres. Consequently, the densities of birds and mammals are low throughout most of the tundra expanses. Thus, even though buildings, airports, roads, and other human constructions may permanently change large areas of tundra and displace tundra wildlife, the actual numbers of animals displaced by individual projects is often small and seemingly insignificant.

Notably, tundra animals are concentrated at certain times and places, and disturbance of these sites may have serious consequences. For example, tens of thousands of caribou concentrate in relatively small areas for calving, and in insect relief areas during mid-summer; thousands of geese concentrate around large tundra lake systems to molt their wing feathers; hundreds of thousands of waterfowl and shorebirds concentrate in productive coastal tundra prior to fall migration; and tens of thousands of snow geese congregate in dry tundra of northern Alaska prior to fall migration.

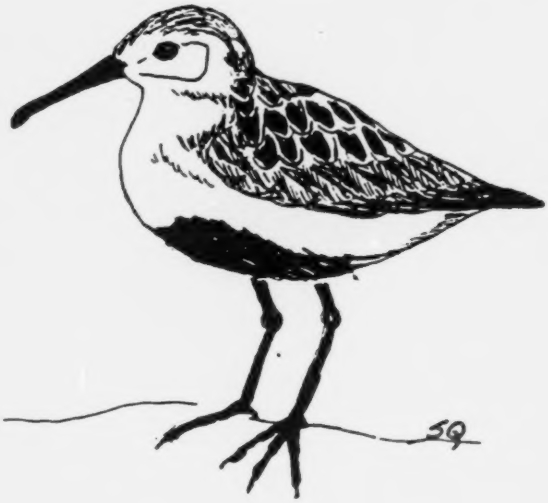
On the other hand, the productivity of tundra ecosystems is a reflection of their vastness. Herds of 150,000-200,000 caribou could not survive if confined to a small tundra area; they would soon overgraze the lichens and other plants and die from lack of food. Nesting birds space themselves throughout available nesting habitat: those that are unable to find or defend a nesting territory simply do not nest. Hundreds of thousands of geese and ducks, and millions of shorebirds, nest in Alaska's wet lowland tundra expanses, making these among the most important bird nesting grounds in North America.

These impressive numbers reflect the vastness of the tundra more than its productivity. Reductions in the amount of tundra available for nesting will inevitably reduce the numbers and productivity of tundra birds.

Additionally, many nomadic tundra wildlife, such as snowy owls, jaegers, and arctic foxes, require vast areas of tundra because the conditions they need for successful reproduction and winter survival do not continuously occur at any one location. These species continually wander from one tundra region to another in search of suitable food supplies, and their numbers would likely decline if considerable areas of tundra habitat were disturbed or developed.

When we assess the productivity and value of the tundra we often think of the cumulative wealth and productivity of its wide expanses. In assessing human impacts, we must also consider the cumulative impacts of all development projects, recreational use, air pollution, and other human activities. Changes in tundra are long-lasting; areas disturbed 50 years ago have still not returned to their original states. Thus, while individual projects may have relatively little impact, the sum total of many projects conducted over a period of many years (or even decades), could significantly and permanently reduce the wealth of waterfowl, shorebirds, and caribou produced in Alaska's tundra ecosystems.

Introductory Activity 5.



Objective:

Students will recognize that careless human activities can affect tundra ecosystems.

Skills:

SCIENCE: synthesizing, inferring, predicting
LANGUAGE ARTS: reading, oral communication

Materials:

Tundra Puzzlers–see following pages.

Procedure:

SUMMARY: Students will use information on the Tundra Puzzlers to figure out how, through ecosystem interconnections, certain human activities can have unexpected and long-lasting effects on tundra ecosystems.

1. PREPARATION: Photocopy the Tundra Puzzlers, so that each student can have a copy of one puzzler. Students may work in groups (all with the same puzzler) or individually.
2. STUDENTS ATTEMPT TO SOLVE THE PUZZLERS: After handing out the puzzlers, explain that students are to use the facts provided on the study sheet to figure out the answer to the puzzle (written at the bottom of the page). To solve each puzzle, students will need to read the information carefully, look for connections in the information, and apply their knowledge of tundra ecology.
3. STUDENTS PRESENT THEIR FINDINGS: Review each puzzler with the class. Have those who worked on each puzzler explain the puzzler and the solution or prediction at which they arrived, based on the facts provided. Have the class discuss the puzzler, then read the solution or prediction of scientists.
4. EVALUATION: Have students describe why scientists are often unable or unwilling to precisely predict the effects of human activities on ecosystems.

Alaska Wildlife Week Unit 6. © 1988 Alaska Dept. Fish and Game

Tundra Ecology Puzzler 1

The Facts:

Mosses, lichens, and flowering plants die whenever they are repeatedly crushed or trampled.

Permafrost, or perennially frozen soil, underlies most of the lowland tundra in Alaska.

Water expands when it freezes. Thus, wet soil that is frozen takes up more room than thawed wet soil.

The active layer of soil that lies on top of the permafrost layer thaws and refreezes each year. The depth of the active layer varies considerably, from 2 inches to several feet, depending on local environmental conditions. Generally, the active layer is more shallow on north-facing slopes and in sites where the soil is insulated by vegetation.

Much of the lowland tundra in northern Alaska receives less than 10 inches of precipitation per year. This is equivalent to the amount of precipitation in a desert.

The rate at which water drains through soil depends upon a variety of factors, including the size and type of soil particles. Water rapidly drains through sand and gravel soil, but percolates slowly through soils made up of clay or organic particles. Water can not drain through frozen soil.

Water from rain and melting snow drains into low-lying spots. Due to underlying permafrost, most of the annual precipitation in lowland tundra remains within or on top of the active layer of soil.

Water is an excellant conductor of heat energy. It absorbs and retains more heat from sunlight than does soil.

All plants have specific tolerances for soil moisture. Some species grow only on dry soils, while others grow only on wet soils.

Most tundra plants grow very slowly, due to cold temperatures, short growing seasons, and the scarcity of minerals in tundra soils.

The Puzzle

Based on the information above, and your understanding of ecology, what changes in the tundra would you expect to occur after a large track vehicle was driven across the tundra?

What changes might you expect if reindeer or caribou were confined to a small area of tundra for several days by fences, roads, or other obstructions? What would be the effects of a hiking trail across permafrost tundra?

Tundra Ecology Puzzler 2

The Facts:

The radioactive isotope cesium-137 is a product of atomic fission reactions such as occurs in the explosion of nuclear weapons and in nuclear power plants. It has a half-life of 30 years, which means that it loses half of its radioactivity every 30 years. (Thus after 60 years, it still has 1/4 of its original radioactivity, and after 90, it has 1/8 its original radioactivity.)

Cesium-137 has been released into the atmosphere by the explosion of atomic weapons in the South Pacific, China, Russia, Japan, France, and in the Aleutian Islands. Atmospheric testing peaked in the late 1950's and early 1960's. Cesium-137 has also been released into the atmosphere as a result of accidents at nuclear power plants.

Lichens obtain the minerals they need mainly from rain and snowmelt.

Cesium-137 has chemical properties that make it react with other chemicals in ways similar to potassium.

Potassium is an essential mineral for living things. It occurs in the cells and fluids of living things. In mammals, the amount of potassium in the blood is regulated by the kidneys. Excess amounts are removed and excreted.

Rain and snow form around particles of dust in the air.

The air in the earth's atmosphere circulates around the globe.

The lifestyles of northern Alaska Natives have been changing. They have become more dependent upon foods shipped in from elsewhere, and rely less on subsistence hunting.

The Puzzle

Based on what you know about tundra ecology, and the above information, explain why higher concentrations of cesium-137 might be found in the tissues of humans and wolves who live in the arctic tundra than in the rain or soil of tundra. Why do you think that the levels of cesium-137 in arctic people has declined in recent years?

Tundra Ecology Puzzler 1

What Ecologists Have Puzzled Out

Disturbance of tundra vegetation by vehicle traffic, or repeated trampling by reindeer, caribou, or humans kills plants and lichens. This effectively removes a layer of insulation from the soil surface. As a result, the exposed soil thaws to a deeper depth than surrounding soils. If the soil is primarily organic or clay soil, and contains water, the thawed soil takes up less space than the frozen soil did originally, so the soil in the site sinks or subsides.

Water drains into the low spots created by the slumping. Although water may percolate through the active layer, it can not seep through the underlying and surrounding permafrost. The collected water absorbs heat from sunlight, so underlying and surrounding permafrost is further melted. When winter returns, the collected water and water-logged soil freeze and expand. The pressure of the expanding ice forces the surrounding soil out and upward, thus enlarging the low spot, while at the same time creating mounds in the surrounding soils. In spring when the active layer thaws again, the frozen, water-logged soil in the site again subsides.

Over a period of years, repeated freezing and thawing enlarges the low-spots orignally caused by disturbance of the vegetation. Ultimately, a large area of formerly dry soil is thus converted to low-lying, wet or submerged soil. The plants that previously grew on the spot can not survive in the wet soil, so they die and can not recolonize the site. Although plants adapted to wet soil may invade, their colonization of the area is necessarily slow (due mainly to slow rates of plant growth in tundra environments).

Thus, as a result of the interconnections between vegetation, water, soil, and sunlight, the effects of a vehicle driving across permafrost tundra, or of repeated and concentrated foot traffic, may change permafrost laden tundra for decades, or in some cases, permanently.

The effects of permafrost disturbance of poorly drained, ice-rich soils can be quite startling--mounds 10-50 feet in diameter, and 1-8 feet in height, separated by trenches 1-5 feet wide, or pits 5-20 feet deep and 3-20 feet across. On slopes, the thawing of permafrost can cause slope failures, mass earth movement, and/or landslides.

Reference: Heginbottom, J.A. 1973. Some effects of surface disturbance on the permafrost active layer at Inuvik, N.W.T. Task Force on Northern Oil Development, Rept. No. 73-16. Information Canada.

Tundra Ecology Puzzler 2

What Ecologists Have Puzzled Out

Cesium-137 molecules are spread widely by air currents once released into the atmosphere. These radioactive molecules settle back to earth, mainly in rain drops and snow flakes. Since lichens obtain their minerals from rain and snowmelt water, and cesium-137 mimics potassium (a mineral they need), lichens rapidly take up and retain cesium-137 in their tissues. Plants also take up and retain cesium-137, but at a slower rate than lichens because they absorb water and minerals from the soil rather than directly from rain and snowmelt. The soil itself traps and filters out some of the cesium-137, and some never reaches the soil as it flows away in run-off waters. In addition, many plants die back and shed their leaves each winter. Most lichens, in contrast, retain the same tissues for years or even decades, and thus may accumulate much of the cesium-137 they absorb.

During some winters, caribou eat mainly lichens. Their bodies respond to cesium-137 in the same way as potassium, by absorbing and retaining it in their body tissues and fluids. The amount of cesium-137 retained by a caribou depends upon its precise diet, and other factors. When caribou feed mainly upon contaminated lichens, they absorb and retain some of the cesium-137 that was originally taken up by the lichens. Humans and wolves who then eat the caribou, similarly take up and retain the cesium-137 from the caribou tissue. Humans and wolves who eat a lot of caribou, that have fed upon heavily contaminated lichens, can end up with surprisingly high levels of cesium-137. In one study, scientists found concentrations cesium-137 in lichens to be 5 times that found in rain and snow, and that in caribou 4 times greater than that in lichens. Humans and wolves had levels similar to or greater than found in the caribou.

However, it is important to note that the retention of cesium-137 by lichens and other members of this food chain varies considerably. Cesium-137 is always transferred through lichen food chains, but concentration does not always occur. The amount and rate of cesium-137 exchange through tundra food chains depends upon many factors, including the level of background contamination, the levels of precipitation and of contamination of lichens, the proportion of contaminated lichens in caribou diets (and what else is in their diet), plus the proportion of contaminated caribou and the kinds of other foods in the diet of the consumers of caribou.

The level of cesium-137 in northern Alaskan Natives has dropped because the amount of radioactive fallout has declined since atmospheric testing of nuclear weapons has become less common. Additionally, Native people are eating more foods imported from elsewhere and less caribou, particularly in spring when concentrations of cesium-137 in caribou is highest (since lichens are the main winter food of caribou).

REFERENCE: W. C. Hansen, 1982. Cesium-137 concentrations in northern Alaskan Eskimos, 1962-1979. Effects of Ecological, cultural and political factors. Health Physics, 42 (4): 433-447.

Tundra Ecology Puzzler 3

The Facts

The following information approximates the reproduction and mortality rates in a population of brown bears living in a region of Alaska's arctic tundra. (Actual mortality figures vary widely.)

Female brown bears in tundra areas do not begin producing young until they are 8 years old, and then have 1 litter about every 4 years. Nearly all female bears have their last litter at about age 20, and die of old age after raising that litter.

In northern tundra areas, female bears give birth to 2 cubs per litter. On average, half of the cubs born are female.

Fights with other bears are a major cause of death among bears. Since male bears fight more often than female bears, they have a higher death rate. Adult and subadult female bears (over 5 years) outnumber adult male bears 3: 2.

Young bears have poor survival rates. About 40% of the cubs die before they are 4 years old.

Bears 4 years and older usually have good survival rates. On average, only about 2% of bears 3 years and older die each year from sources other than human-caused deaths. Most of these deaths are the result of fights among bears, accidents, and disease. Humans kill brown bears to obtain their fur. The number of bears harvested by hunters is limited by regulations. Female bears with cubs can not legally be killed. Regulations allow people to harvest about 3% of the brown bears in a tundra population each year. The combination of natural deaths and legal harvest of bears by humans imeans that about 20 percent of the adult females die every 4 years. That is, 20 percent do not survive to raise another litter of cubs.

Bears are also killed by people whenever they are considered a threat to human life or property. Since the behavior of brown bears around humans is difficult to predict, and because humans fear brown bears, bears are frequently killed whenever they come in contact with people. Females with cubs are often killed. The number of bears killed for this reason can not be controlled by regulations.

Brown bears are omnivores. In northern Alaska, over 70 percent of their diet is vegetation. They also feed on ground squirrels, marmots, bird eggs, and caribou. They also scavenge dead animals.

Due to their omnivorous food habits and the scarcity of food in tundra areas, bears are easily attracted to human garbage dumps. They quickly learn to associate human smells with food.

In northern tundra areas, individual brown bears have very large home ranges. They travel over areas of 60-700 square miles in search of adequate food supplies.

In order for a bear population to remain healthy, or grow larger, each female bear must produce at least 1 female young that survives to breed. (That is one female bear to replace her when she dies.)

The Puzzle

Based on the above information, how many cubs could a single female brown bear living in an arctic tundra area produce in her lifetime, if she survived a full lifespan? How many of these would survive to age 4 years? To breeding age (8 years)?

What is the maximum number of female young that 100 female cubs could produce given the above mortality rates? (Calculate how many survive each 4-year period of their lives to produce a litter of cubs, then multiply that number by the number of cubs produced. Divide by half to find out the number of females.) How many of these would survive to breeding age? Considering the above reproduction and mortality (death) rates, would the bear population remain stable, increase, or decrease?

Imagine yourself as a bear biologist with the above information about a population of brown bears in the arctic. How do you predict increasing human populations and development in the habitat of this population will affect it?

TUNDRA ECOLOGY PUZZLER 3. What Scientists Predict

Due to the slow reproductive rates of tundra brown bears, their populations grow slowly even under undisturbed circumstances. In the example given, 1 female will produce 8 cubs in her lifetime, of which 4 will females. Only 2.6 of the females will survive 4 years, and only 2 to breeding age. If you calculate the survival of the 100 female cubs born, you will find that 40 survive to 4 years, 32 to age 8 (when they produce 32 female cubs); 27 to age 12, 22 to age 16, and 18 to age 20. By adding up the number of female cubs produced, (remembering that cubs are only produced every 4 years on average) you should find that 99 female cubs would be produced by each 100 female cubs born. This is just barely enough to keep the population stable.

Since bears are wide-ranging, and are attracted to human settlements, increasing human populations and development inevitably lead to more human-bear encounters. Since human-bear encounters often result in the bear being killed, the consequence of increasing human populations and development in tundra regions of Alaska is certain to increase brown bear mortality. A bear biologist who found the production and mortality rates given in the example would have to conclude that development would be likely to lead to a decline in brown bear populations.

Brown bears formerly ranged throughout the Lower 48 south to Mexico. Today only two small populations remain; one in the remotest regions of Yellowstone National Park and the other in Glacier Bay National Park. Human encroachment into formerly wild areas has been the main cause of the disappearance of brown bears from their formerly extensive range. Today harvest regulations help to prevent humans from killing too many bears, but when wild areas are developed, human-bear encounters increase, and so does the number of bears killed by humans. In tundra regions, where bear production is low and where individual bears must travel vast areas to find adequate food, scientists consider it very likely that increasing development will lead to bear population declines.

The information provided in the example is based on research by the Alaska Department of Fish and Game in northern Alaska. However, the actual reproduction and mortality rates of brown bear populations vary considerably from place to place and year to year. In other environments, reproduction rates are higher. Brown bear populations can withstand low levels of human harvest, but small increases in the number of bears killed can cause a population decline.

TUNDRA ECOLOGY PUZZLER 4.

The Facts:

Lichens are a symbiotic association of two kinds of living things. These include an algae, which photosynthesizes food, and a fungi, which provides a protective shell and helps absorb water and minerals from the environment. Lichens grow on the soil, rocks, and on wood.

Chlorophyll molecules are found in leaves of plants and in algae cells. These molecules capture the sunlight energy used in photosynthesis.

Lichens mainly reproduce vegetatively. Vegetative reproduction does not occur on acidic substrates.

Lichens obtain water and minerals primarily from rain and snowmelt water. They dry out in an absence of moisture, but soak up moisture like a sponge when it becomes available.

Lichens live for many years and absorb air and water-borne particles much more quickly than plants. This results in high concentrations of certain chemicals in their tissues.

Burning of fossil fuels (oil, gas, coal, and wood) releases a variety of chemicals into the air, including, among many others, nitrogen dioxide, carbon dioxide, carbon monoxide, and sulfur dioxide.

The atmosphere is made up of several layers of air. The layers of air are constantly mixing and moving due to changes in air pressure, temperature, and moisture content. Large masses of air often travel thousands of miles over the earth's surface.

Smoke, from industries and power plants that burn fossil fuels, often causes air pollution problems in nearby areas. These problems have been reduced by building very tall smoke stacks. These send the smoke higher into the atmosphere where much of it is dispersed by winds and thus prevented from settling in nearby surrounding areas.

Wind-blown dust and smoke are the main sources of the dust particles in the air.

Lichens are an important winter food of caribou.

When air pressure conditions are suitable, the water vapor in clouds condenses around dust particles and falls back to the earth as rain or snow. The precipitation carries the dust particles back to earth.

The pH of soil, rocks, and wood is affected by the acidity of the precipitation.

Many chemicals are soluble in water. That means they dissolve, or become thoroughly mixed with water. The amount and kinds of chemicals dissolved in water determine the pH of the water. Concentrations of certain chemicals cause water to have a low pH, or become acidic. These include sulfer dioxide and nitrogen dioxide. Other chemicals cause water to have a high pH, or become alkaline.

Sulpher dioxide and nitrogen dioxide, and compounds derived from these, change chlorophyll molecules so that they no longer function.

The Puzzle

Based on the above information and your knowledge of ecology, explain how caribou populations of Alaska could be affected by industrial development in western Europe. What else might be affected?

Tundra Ecology Puzzler 4. What Ecologists Predict

The potential for air pollution in western Europe to affect caribou populations in Alaska is, at present, only speculation. However, the potential effects are cause for concern. Sulphur dioxide and nitrogen dioxide are released by burning of fossil fuels. As a result of air currents and movement in the upper atmosphere, these and other compounds can be carried thousands of miles from the place where they were released into the atmosphere. When water vapor in clouds condenses and falls to earth as precipitation, it carries particles of dust with it. Sulphur dioxide and nitrogen dioxide particles dissolve in water, and make precipitation acidic. "Acid rain" is thus a result of air pollution, and often a result of air pollution created great distances away.

Acid rain has been shown to be a problem in tundra regions of Norway and Sweden. It has not yet been shown to be a problem in arctic Alaska, but many scientists are concerned that it will become a probelem in the near future. Air currents in the northern hemisphere carry air from western Europe and the Soviet Union into arctic Alaska. Pollution from these sources are considered part of the cause of the "arctic haze" which has appeared in northern Alaska in recent years. Local industrial development and increasing human populations, with accompanying use of fuels for vehicles, heating, and production of electricity, also contribute to increasing air pollution problems in the arctic. Consequently, scientists consider acid rain a potential problem in some parts of arctic Alaska.

Acid rain has two serious consequences for lichens. Sulphur dioxide and nitrogen dioxide, whether dissolved in water to form acid or in particle form, interfere with the functioning of the chlorophyll molecules in algae, and thus prevent photosynthesis. Unable to make their own food, the algae and the dependent fungi both die. In addition, acid rain acidifies the substrates on which lichens grow: soil, rocks, and wood. Since lichens are unable to grow on acidic surfaces, acid precipitation can also prevent lichen growth and establishment.

Since acid rain can kill or decrease growth of lichens, and lichens are a primary winter food of caribou, acid rain in tundra regions of Alaska and Canada could cause declines in populations of caribou. Due to food chain connections, consumers of caribou, including wolves, bears, and humans, would ultimately be affected. Similarly, populations of other consumers of lichens, and populations of their predators, could also be harmed. Due to the complex web of interconnections in tundra ecosystems, other ecological changes might also occur as a result of the effects of acid rain on lichens. Lichens are important insulators of the soil, are used as nesting material by some birds, and may have other as yet unknown functions.

References:

Schofield, E. 1975. Some considerations on the possible effects of local and global sources of air pollution on lichens grazed by reindeer and caribou. In Proceedings of the First International Reindeer and Caribou Symposium. 1972. J. Luick, P.C. Lent, D. R. Klein, and R. G. White, Eds. Biological Papers of the University of Alaska, Special Report Number 1.

Hale, M. E. 1983. The biology of lichens. Edward Arnold (Publishers), London.

TUNDRA IMPRESSIONS ....LANGUAGE ARTS, MATH, SOCIAL STUDIES

OBJECTIVES: Students will recognize that different people react differently to tundra environments, and will recognize that what people say or write can influence the thoughts and feelings of others.

SKILLS: Language Arts: reading, oral discussion, writing, Math: averaging or graphing; Social Studies: opinions, values assessment

MATERIALS: Copies of the excerpts from writings about Alaskan tundra from below and the next page

PROCEDURE:

1. STUDENTS READ DESCRIPTIONS OF TUNDRA: Divide the class in half. Assign Group 1 to read the descriptions of tundra given on page ---, and the other half (Group 2) to read the descriptions presented on page ---.

2. STUDENTS EXPRESS THEIR AGREEMENT / DISAGREEMENT WITH STATEMENTS ABOUT THE TUNDRA. Write the following on the board: Strongly Agree-1, Agree-3, Agree Slightly-5, Disagree Slightly-7, Disagree-9, Strongly Disagree-11. Explain that you want students to write down their opinion about the statements you will read. They should record the number next to the statement that best expresses their opinion.

2. STUDENTS REACT TO STATEMENTS ABOUT THE TUNDRA: Read the following statements and have students write down their reactions--

The tundra is a harsh, cruel environment.
The tundra is beautiful.
The tundra is a barren wasteland.
The tundra is an incredible wilderness.
The tundra is a rich environment full of interesting plants and animals.
The tundra has little value as it is.

3. STUDENTS COMPARE THE ANSWERS OF THE STUDENTS IN EACH GROUP: Have each group get together and tally the opinions of their group for each question. Students can calculate an average score for a question by averaging the numbers recorded by members of the group. (Alternatively, students could make a bar graph for each question to show the distribution of answers.) After both groups are finished tallying, compare the average scores or bar graphs for each answer. Was there any difference in the two groups answers?

4. STUDENTS READ THE ALTERNATE DESCRIPTIONS OF TUNDRA. Have each group read the alternate descriptions of tundra. Have the class then discuss the contrasting impressions of the writers, and whether or not the writings influenced student reactions to the various statements. (Was there a difference in the average scores of the two groups? Was one group generally more positive about the tundra?) What factors do students think contribute to their different feelings about tundra, and those of the various writers?

5. STUDENTS VISIT A TUNDRA SITE, THEN WRITE THEIR OWN DESCRIPTIONS AND IMPRESSIONS OF TUNDRA. If possible, visit a tundra site. Even if students live in a tundra area, have them walk through a tundra area and try to get a sense for the land and their own feelings about it. You may want to end by reading student descriptions, and /or the quotation from Arctic Dreams given in the adjacent column.

"To a modern traveler the arctic landscape can seem numbingly monotonous, but this impression is gained largely, I think, from staring at empty maps of this region and from traveling around it by airplane.....The plane is a great temptation, but to learn anything of the land, to have any sense of the relevancy of the pertinent maps, you must walk away from the planes. You must get off into the country and sleep on the ground, or take an afternoon to take a tussock apart. Travel on the schedule of the muskoxen. Camp on a seward point and watch migrating seaducks in their days of passage. You need to stand before the green serpentine walls of the Jade Mountains north of the Kobuk River, or walk out over the sea ice to the flaw lead in winter to hear the pack ice grinding and scraping....When you have walked for days under the enormous sky; when you have felt the remoteness of the world from the Thomsen River country of Banks Island; felt the unquenchable exuberance of sled dogs cracking off the frozen miles down a river valley; or been shown how some very small thing, like a Lapland longspur eating the lemming's bones for calcium, keeps the country alive, you begn to sense the timeless, unsummarised dimensions of a deeper landscape."

Excerpt from Arctic Dreams, by Barry Lopez, Charles Scribner's Sons, 1986.

"Sixty miles of rolling hills, much like the rolling hills between the Yukon and Fairbanks, only more of them, and barren, dead, wind-swept, not a living thing, no scrub timber, no vegetation save the short tundra moss that lies--much of it frozen--between the snow and the ground. And wind! It was continuous. The snow like pebbles cut our faces."

"It takes a Northman to survive the North. Not only the cold--the actual physical fact of freezing in some ice-bound cavern underneath Alaska's ice-bound rivers--but the terrible, silent menace of it, the soundless days without end, when the thought of being the only human in some vast stretch of its white wastes, is too terrifying a thought for one companion-loving human to carry and keep his mental balance!"

Excerpted from: Tundra: romance and adventure on Alaskan trails. by A. C. Edington. The Century Co., New York, 1930.

"For a whole day we paddled up this winding creek, which split up so frequently that nobody without local knowledge could possibly keep the right course, and at sundown camped fairly on the edge of the tundra, carrying the canoe and part of the cargo over the first portage to a small lake. A gloomy, desolate strip of country is this marshy tundra, with its countless lakes and sluggish streams, especially as we saw it this night in drenching rain, which only seemed to pause a few moments to give the mosquitos a fair chance to annoy us. But there was still enough willow scrub for firewood, and even a few spruce trees were scattered about over the long stretches of morass, rendering the landscape far less wearisome than in other parts of the tundra, where there is absolutely nothing to break the dull gray level."

Excerpt from: Through the Subarctic Forest, by Warburton Pike, 1896

"When the moon rode high in the heavens, throwing a ruddy glow upon the wind-whipped snow, we often took our dogs for an enjoyable run across the tundra. Even the storms were interesting. I remember a sullen day when there was scarcely any lightening of the sky at noontime; a steady north wind was blowing, and snow drifted over the tundra like a veil; but then in the blackness of nid-afternoon the wind dropped, not a breath of air stirred, and the mournful howls of uneasy malemutes could be heard across the village. The silence was so intense that the crackling of the ice far out on the ocean was as loud as gun shots; the night turned clear, and the deep-set stars shone brilliantly from the moonless sky.

Then, without warning, the wind shifted to the south, and in a few moments a hurricane of driving, swirling snow was blowing so thick, the Eskimos did not dare leave their igloos to go to their caches a little distance away without a line to guide them back to safety. It was not cold, as Arctic weather goes, being less than twenty degrees below zero, but it was impossible to keep our room warm. Our little sheet-iron stove was red hot, and we sat so close to it we singed the fur on our parkas, yet our offside hands were cold.

When the winds had passed, however, we were always repaid by electrical displays overhead. It was after such a gale in early December, the driving snow obscuring everything a few feet away, that the wind dropped suddenly. My notes for December 12 read:

There was a wonderful aurora last night, the first I have seen showing colors other than pearl and mist green. The rapidity with which the flaming area of light changed from mere streams of mist to rolling scrolls crossing from west toward the east was wonderful. The stars shone coldly and brilliantly out of a sky of darkest blue--blue black--while the three quarters full moon lighted the snow-covered tundra with a greater brilliance than any of the dark, sunless days of winter. It was snapping cold and quiet; the crunch of snow and howl of the malemutes carried for long distances, while the lights from the gut windows of the igloos blurred orange in the velvet blueness of the Arctic night.".

Excerpt from: Field Work of a Museum Naturalist, Alaska--Far North, 1919-1922. Alfred M. Bailey. Denver Museum of Natural History, Museum Pictorial No. 22. 1971.

"How precious and fertile the ground is made to seem, when every square foot of it is an exquisite elfin garden made by the little people. at infinite cost, filled with dainty flowers and still later embellished with delicate fruit....There were leagues and leagues of caribou moss, pale green or lilac, and a hundred others in clumps, that seeing here the glory of the painted mosses, were simulating their ways... I never before saw such a realm of exquisite flowers so exquisitely displayed, and the effect at every turn throughout the land was colour, colour, colour (sic)....What Nature can do only in October elsewhere, she does here all season through, as though when she set out to paint the world she began on the Barrens with a full palette and when she reached the Tropics had nothing left but green. Thus at every step one is wading through lush grass or crushing prairie blossoms and fruits. It is so on and on; in every part of the scene, there are but few square feet that do not bloom with flowers and throb with life; yet this is the region called the Barren Lands of the North.

And the colour is an index to its higher living forms, for this is the chosen home of the Swans and Wild Geese; many of the Ducks, the Ptarmigan, the Lap-longspur (sic) and Snowbunting. The blue lakes echo with the wailing of gulls and the eerie majic calling of the Loons. Colonies of Lemmings, Voles, or Ground-squirrels are found on every sunny slope; the Wolverine and the White Wolf find this land of plenty, for on every side, as I stood on that high hill, were to be seen small groups of caribou...."

Excerpted from: The Arctic Prairies, by Ernest Thompson Seton, London, 1912

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EXAMINE THE ISSUES.. INDOORS..SOCIAL STUDIES / SCIENCE

OBJECTIVES: Students will become familiar with a current issue related to Alaskan tundra and recognize the importance of obtaining information on an issue before forming a decision.
SKILLS: collecting and gathering information, issue evaluation, decision-making
MATERIALS: Paper and pencil, magazines, newspapers, and other material related to a selected issue, two signs with the words "Agree" and "Disagree."
PROCEDURE:
1. STUDENTS SELECT AN ISSUE: A variety of issues exist relating to tundra areas of Alaska. Students should first identify an issue that relates to their local area, or one in which they have a particular interest by reading through local newspapers or by reviewing the following list. Have students vote on the issue they are most interested in finding out more about.
CURRENT TUNDRA ISSUES
--Oil and gas exploration and development in the Arctic National Wildlife Range*
--Opening of the Dalton Highway to the public
--Use of off-road vehicles in tundra areas by recreationists, miners, hunters, and others
--Waste disposal and water pollution at oil exploration camps, and in towns and villages in tundra areas,
--the effects of the pipeline and Prudhoe Bay
--Possible oil and gas development in the Colville River Delta
--Oil and gas leasing of the Teshekpuk Lake area (a goose staging area of international importance)
--Development of the Red Dog Mine near Kotzebue
--Goose management problems in the Yukon-Kuskokwim River Delta.
2. STUDENTS RESEARCH THE ISSUE: After selecting an issue, have students write one sentence describing their opinion of how the issue should be resolved. Place the "Agree" and "Disagree" signs on opposite sides of the room. Then read each student statement (group similar ones) and have students show their agreement or disagreement with each statement by standing near the Agree or Disagree sign. Record which resolutions of the issue receive the most agreement.

Next, have students determine the individuals and groups likely to have an interest, or position, related to the issue. Students should then write a letter to each of the interested parties to request information about their position. While waiting for replies, have students gather articles and relevant information from local and national newspapers and magazines. Students might also invite speakers to the class, or interview individuals with an interest or knowledge about the specific issue. Stress the importance of obtaining and examining information and viewpoints from all sides of the issue.
3. STUDENTS REVIEW OPPOSING POSITIONS: Have students read and evaluate the positions of all interested individuals and organizations. If desired, assign individuals or groups to role-play each of the interested parties. Then, hold a hearing on the topic.

Once again, have each student write a sentence describing how he/she thinks the issue should be resolved. Repeat the process of having students demonstrate their agreement or disagreement with each resolution by standing under the appropriate sign (in this step they represent themselves--not the group or individual they role-played). Compare the statements that received the most agreement this time with those that received the most approval before students researched the issue. Discuss why there is or is not a difference.

EVALUATION: Have each student write an essay stating what he/she thinks is the best resolution of the issue, what they see as the positive and negative consequences of their resolution (for people and tundra ecosystems), and how they would minimize the negative consequences. Students should demonstrate an understanding that any decision has both positive and negative consequences.

*At the time of this writing (1988), oil exploration and development in the Arctic National Wildlife Range is one of the most prominent issues relating to tundra ecosystems. Two groups on opposing sides of this issue have prepared videotapes stating their viewpoints and have made these available to the public at cost. Check-out copies are also available in some areas. These contrasting programs provide an interesting look at the Arctic National Wildlife Range issue and provide a good basis for class discussion of this topic.

For presentation of the oil industry's viewpoint, send $12.50 for a copy of "ANWR-Decisions for Tomorrow" to Alaska Oil and Gas Association, 121 W. Fireweed Lane, Suite 207, Anchorage Alaska 99503, ATTN: Ardie Merbs (available in 1/2 inch VHS only, 16 min.).

For presentation of an environmental organization's viewpoint, send $15.00 for a copy of "Arctic Refuge--Treasure of the North" (Specify VHS or Beta, 35 min.) to Northern Alaska Environmental Center, 218 Driveway, Fairbanks, AK 99701, ATTN: Video.

Design a Town..
Indoors / Outdoors..Social Studies / Science

OBJECTIVES: Students will demonstrate an understanding that human activities can be modified to lessen their impact on the environment.
SKILLS: creativity, critical thinking, application of science concepts to social problems
MATERIALS: paper and pencils; optional: local experts
PROCEDURE:
1. STUDENTS DETERMINE THE IMPACTS OF THEIR TOWN ON THE TUNDRA (Or other local environment): Students should look at their own town, and develop a list of the ways people are changing or harming the surrounding environment. If possible, encourage them to look for evidence of the following and determine the sources of each problem: air pollution, water pollution, permafrost melting, accumulation of waste materials, and reduction of local wildlife populations. Encourage students to observe carefully, and if possible, contact local experts to find out which of these are problems in their community, and to determine why the problems exist. Have the class make a list of the human impacts they find, and the causes of each.
2. STUDENTS DESIGN A TOWN IN WHICH HUMAN IMPACTS ARE MINIMIZED: Divide the class into groups, and have each group design a tundra town where the above impacts of humans are minimized, but where each of the following problems is solved. Each group should be able to explain how or why their solution to the problem will reduce the human impacts discovered above:

a. Where and how will the town's residents obtain their food?
b. What construction methods will be used to prevent damage to the tundra?
c. How will residents heat their homes, cook, and move from place to place? Where will the energy come from?
d. Where will residents obtain water?
e. How will human wastes and garbage be disposed?
f. What will the people do to earn a living?
g. What will make this town a pleasant place for people to live?

Allow students free reign within the following guidelines. Student solutions must be realistic; their solutions must actually work (in other words they can not say that they will heat their homes by nuclear fusion, since this is a process that is not available based on current technology).

3. GROUPS PRESENT THEIR SOLUTIONS TO THE CLASS: After student groups have had adequate time to develop their designs, have each group present their plan to the class. Then, have the class select the best town design. Finally, encourage group cooperation, by having the class work together to improve or polish the selected town design. They can do so by evaluating the side effects of each solution, and figuring out a way to reduce or prevent the undesirable effects
For example: if food is flown in from elsewhere--a side effect will be air pollution from the jets. The air pollution might be reduced by having the food brought in by some other means. Or, students may choose to select a totally different solution proposed by one of the other groups. In the end, the class will likely develop a plan that incorporates some of the solutions from all groups.

4. EXTENSION: Have students evaluate whether any of their methods of reducing human impacts could be used in their own town. If so, encourage them to develop a plan for how the solution might be implemented in their town. If possible and appropriate, have students present their plan to the proper governing officials.

Worksheet 5.

GEE WHIZ QUIZ

True or False?

1.________Snow helps keep the soil warm.
2.________Plants make food from sunlight.
3.________Some insects sleep through winter.
4.________Lemmings have young during winter.
5.________Mosquitos are an important part of the tundra ecosystem.
6.________It takes decades for an orange peel to decay in a tundra environment.
7.________The tundra is a wasteland.
8.________Thousands of birds from South America nest in Alaska's tundra.
9.________A bird that lives in Asia and Africa during winter nests in Alaskan tundra.
10.________Permafrost ground will sink if the tundra moss cover is taken away.
11.________Some tundra lakes have turned into hills.
12.________More than one hundred thousand animals live in every square foot of soil of the tundra surface.
13.________Most plants couldn't live without fungi.
14.________Mountain goats can climb straight up a cliff.
15.________Alaska's lowland tundra is some of the most important bird nesting habitat in North America.
16.________Some animals can be frozen and still come back to life.
17.________The wind doesn't blow as strongly at ground level as it does a few inches above the ground.
18.________The air helps keep the earth warm.
19.________Ptarmigan grow their own snowshoes.
20.________Some lemmings turn white in winter.
21.________Tundra hares travel in large herds.
22.________Alaska marmots crowd together in a single den during winter.
23.________There are more kinds of carnivores than herbivores in tundra ecosystems during summer.
24.________A tundra plant has roots that go dozens of feet down into the ground.
25.________The tundra is like a desert.
26.________The tundra is a wetland.
27.________Some of the oldest living things on earth live in tundra.
28.________Few living things occur in tundra.
29.________Some tundra plants grow 6 feet tall.
30.________Most tundra flowers are 1 year old before they bloom.
31.________Some tundra plants are only 1/2 inch tall when they are 50 years old.
32.________Tundra plants and animals use antifreeze.
33.________Some tundra animals make hay.
34.________The wind carries heat.
35.________Most tundra plants grow only a few inches tall.
36.________Most of the tundra on earth occurs in the northern hemisphere.
37.________Some lichens live 1500-4500 years.
38.________In some places on the North Slope, the permafrost is 1000 feet deep.
39.________In some places, only the top 12 inches of soil thaw out in summer.
40.________Tundra covers 1/20th of the land on earth.
41.________Certain bumblebees are active when the air temperature is below 0° F.
42.________The largest caribou herd in Alaska included over 175,000 animals in 1986.
43.________The tundra is a productive environment in comparison to most other environments.
44.________The tundra is too cold for mushrooms and other fungi to grow.
45.________Lowland tundra is perfectly flat.
46.________Arctic foxes eat less in winter than in summer.

Alaska Wildlife Week Unit 6. © 1988 Alaska Dept. Fish and Game

Reference List

The following references were used in preparing this set of teaching materials. They are listed according to subject to aid those interested in obtaining more information on the topics covered in this unit. Asterisked materials are those likely to be of most use to educators.

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TEACHING ACTIVITIES

Audubon Adventures. Audubon Month 1988 poster and leader's guide. "Alaska Tundra--arctic wilderness." Send $8.00 to Audubon Adventures, National Audubon Society, 613 Riversville Road, Greenwich, Conn. 06831

Alaska Department of Education. Ecosystems of the Great Land--Instructional Videos--Arctic and Alpine Tundra. Available from Alaska State Film Library. Video and teacher's guide.

Alaska Department of Fish and Game--Nongame Wildlife Program, Game Division. Alaska Wildlife Week Educational Packets. (Past units on wetlands, ecology, and wildlife populations contain activities and information relevant to the tundra theme.)

Alaska Sea Grant College Program. Alaska Sea and River Week Curriculum Series. University of Alaska Fairbanks. This excellant set of materials contains many activities useful for studying wet tundra ecosystems. Send for a list of guides and costs.

National Wildlife Federation. National Wildlife Week Education Packet. These materials cover a new theme each year, and include a poster, activities, and stickers. Write: National Wildlife Federation, 1412 Sixteenth Street, N.W., Washington, D. C. 20036

Outdoor Biological Instructional Strategies. Delta Education, Box M, Nashua, N.H. 03061. This excellant set of materials includes 97 activities for outdoor study and discovery. Send for information on costs.

Western Association of Fish and Wildlife Agencies and Western Regional Environmental Education Council. 1983. PROJECT WILD. Excellant activities relating to wildlife and wildlife conservation-national scope. *For information and training contact: Dolores Scott, Alaska Dept. of Fish and Game, Game Division, P.O. Box 3-2000, Juneau, AK 99802*

The following cross-reference of this Alaska Wildlife Week Teacher's Guide and Project Wild was provided by Dolores Scott

AWW	Project Wild
Lesson 1	Habitat Lap Sit - using tundra components
Lesson 2	Forest In A Jar - adding steps with freezing the jar with seeds or exposing it to wind
Lesson 3	Surprise Terrarium
	Rainfall and the Forest - use temp. instead of rain
	Adaptation Artistry
	Tracks
	The Thicket Game
Lesson 4	Interdependence
	Good Buddies - use arctic animal example
	Owl Pellets
	Muskox Maneuvers
	Oh, Deer (using geese or caribou)
	How Many Bears Can Live In This Forest - use tundra instead
Lesson 5	Planting Animals
	Who Lives Here
	Here Today, Gone Tomorrow
	Litter We Know

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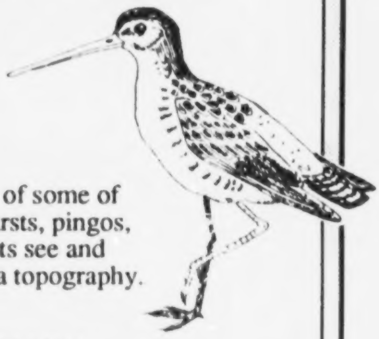
Supplement to the 1988 Alaska Wildlife Week Teacher's Guide



The following pages include:

- **A GUIDE TO COMMON PERMAFROST FEATURES**

  This 5-page summary includes text, drawings, and photographs of some of the common topographic features of tundra, including thermokarsts, pingos, polygons, solifluction, and frost boils. Use these to help students see and understand the effects of seasonal frost and permafrost on tundra topography. These can be posted on a bulletin board.

- **LIVING THINGS IN TUNDRA ECOSYSTEMS--A SUMMARY**

  This 3-page section provides an overview of the kinds of living things found in tundra ecosystems. Representatives of all 5 kingdoms of living things occur in tundra ecosystems in Alaska. This 3-page section provides an overview of the kinds of wildlife present, and their relative abundance. These pages may be posted on a bulletin board.

- **TUNDRA WILDLIFE CARDS**

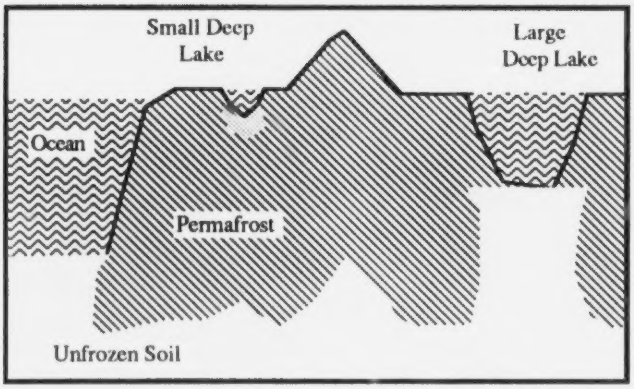
  Over 100 illustrations of tundra wildlife, with text. The most common and easily recognized plants, animals, fungi, and microscopic organisms found in Alaskan tundra are represented in these cards. The cards represent a variety of taxonomic levels because some kinds of organisms are more easily identified than others. Many of the bird and mammal cards represent a single species, or genus, of animal. In contrast, most of the invertebrate, fungi, and microscopic organism cards represent larger groups of organisms, such as family, class, or order. Please note that some of the species shown have limited distributions within Alaska (e.g., pika and mountain goat). Use these cards for reference about the food habits, habitat needs, symbiotic associations, and adaptations of tundra animals. Or, cut up and laminate them to use as flashcards, for card games, or concentration games. Photocopy the illustrations and have students color and cut them out--use as wildlife badges. Use an opaque projector to enlarge the drawings for worksheets, displays, life-size cut-outs, etc.

- **WILDLIFE ADAPTATION CARDS**

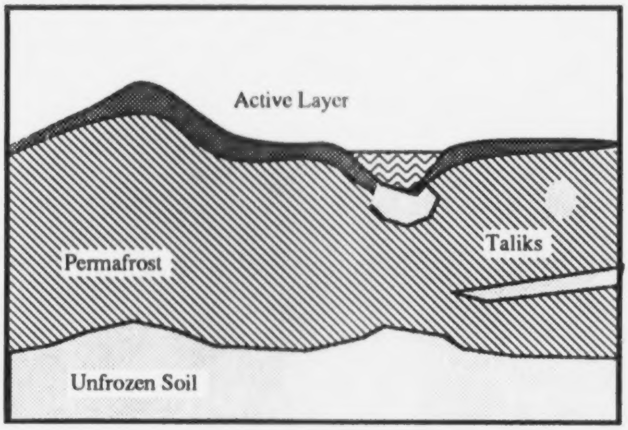
  These cards are intended for use with Lesson 3. in the Teacher's Guide. They include text about and illustrations of 32 species of wildlife, one-half species that occur in tundra, and one-half about non-tundra wildlife. Cut out and laminate the cards. If desired, tape over the name of the animal and/or its habitat, so students can reason out where each organism lives based on the adaptations and traits described on the card.

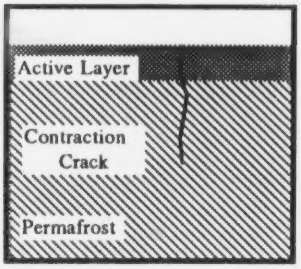
- **KEY TO TUNDRA POSTERS**

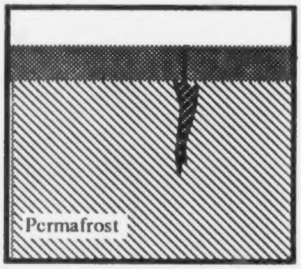
  A list of the plants and animals included in the illustrated posters of lowland and alpine tundra.



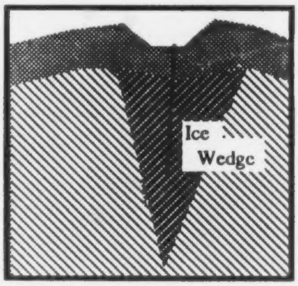
The occurrence and depth of permafrost is affected by the presence of deep lakes, hills, and the ocean. Small deep lakes are underlain by a bulb of unfrozen soil. Permafrost is absent from beneath large deep lakes, and most ocean areas.







Ice wedges are formed by drainage of water into a contraction crack in the soil, followed by winter freezing and expansion. The ice wedge grows larger each year, forcing surrounding soil out and upward..



Permafrost

Permafrost is perenially frozen ground, or ground in which a temperature below 32° F (0° C) has existed continuously for two or more years. Permafrost may contain ice (ice-rich permafrost) or be frozen soil with little or no ice. The upper surface of the permafrost is called the permafrost table. Little water can penetrate this table, so it acts as a barrier to water movement through the ground.

Continuous permafrost underlies the tundra of arctic and northwestern Alaska. In these regions, the ground is frozen everywhere except the soil under lakes and rivers that do not freeze solid in winter. Permafrost can extend up to 2,240 feet (700 m) below the soil surface. Below this, heat from the earth's core keeps the ground thawed.

Discontinuous permafrost underlies the tundra and forests of interior and southwestern Alaska. In these regions, the ground is perennially frozen in some places, but is permafrost free in other sites, such as south-facing slopes, sites where vegetation has been disturbed, and under lakes and rivers.

Active Layer

The active layer is the surface layer of soil that lies on top of permafrost soil, and which thaws and refreezes every year. The depth of the active layer varies from about 12 in (30 cm) to 10 feet (3 m) depending upon the local climate. Near Barrow, the active layer is about 12 (30 cm) inches deep.

Talik

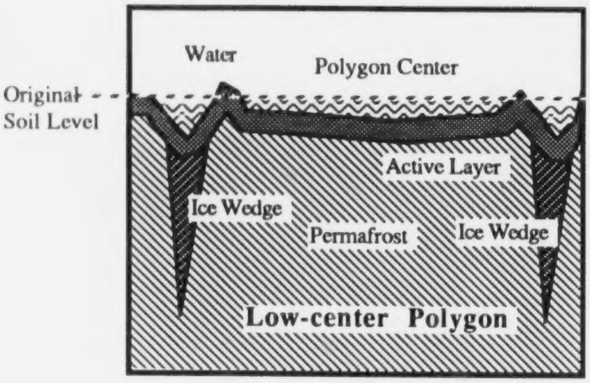
Layers and pockets of unfrozen soil that occur within permafrost soil are called taliks.

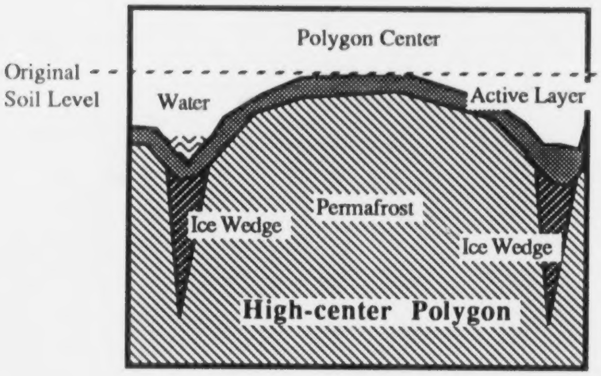
Ice Wedges

Soil contracts, or shrinks, during periods of intense winter cold. As the soil contracts, it cracks. Often, the cracking makes a loud sound. The cracks usually form a polygon (a many-sided geometric shape). The winter that it forms, a contraction crack is only 3/8 in (8-10 mm) wide. During spring snowmelt and summer rains, water flows into this crack and is trapped and frozen by surrounding permafrost. The expansion forces caused by freezing water push surrounding soil upward and outward. Over many years, the crack is gradually enlarged by the freezing and expansion of trapped water, and repeated winter cracking. Ice wedges may grow to be as much as 33 feet (10 m) across, and extend 33 feet (10 m) below the surface. Some large ice wedges may have taken 1000 years to form.

Photo by Ken Whitten

Polygons


Water
Polygon Center
Original Soil Level
Active Layer
Ice Wedge
Permafrost
Ice Wedge
Low-center Polygon


Polygon Center
Original Soil Level
Water
Active Layer
Permafrost
Ice Wedge
Ice Wedge
High-center Polygon

Polygons can form in permafrost areas and in areas with seasonal frost. Most polygons in permafrost areas are formed as a result of contraction cracks in the ground and the formation of ice wedges.

The pressure created by the ice wedge forces the soil around the crack upward to form 2 small ridges [up to 1 1/2 feet (0.5 m) tall]. This creates a polygonal shape of raised edges, or a low center polygon.

In poorly drained sites, water fills the center of the polygon and the center of the ice wedge troughs. Collected water efficiently conducts heat from sunlight so it melts underlying permafrost, which causes additional slumping. As the water-filled troughs and centers enlarge and deepen, they eventually meet to form a small lake. When such a lake is drained, or filled in with organic material from aquatic plants, new low-center polygons form. Over a period of hundreds of years, poorly drained sites may gradually cycle between flooded, low center polygons, and small lakes.

In well-drained soil, the troughs around a low center polygon tend to enlarge and sink, while the center remains in place. This results in the appearance that the center of the polygon is raised, when actually, the troughs have sunken. The center may be 5 feet (1.5 m) above the bottom of the troughs. As the thermokarst slumping caused by the growing troughs continues, the mound may eventually collapse, too.

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Thermokarst slumping of the tundra caused by vehicle tracks.

This photograph of fresh cat tracks across the tundra was taken at Storkersen point, north of Prudhoe Bay, in 1971. Note the disturbance of the vegetation, and compaction of the soil in the ruts.

This 1976 photograph was taken at the same location as the photograph above (Storkersen point, north of Prudhoe Bay) . Five years after the disturbance, the tracks have formed thermokarst depressions, and water from surrounding areas now accumulates in the ruts rather than in the locations it had accumulated previously. Note that few plants have colonized the tracks after five years.

This 1971 aerial photograph shows a summer view of a winter road across the tundra near Oligtok Point. Note how thermokarsting of the winter road has affected the surrounding tundra by causing drainage of both large and small lakes.

Photos by Tom Rothe

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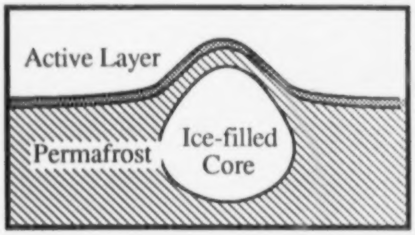
Photo by Bob Stephenson

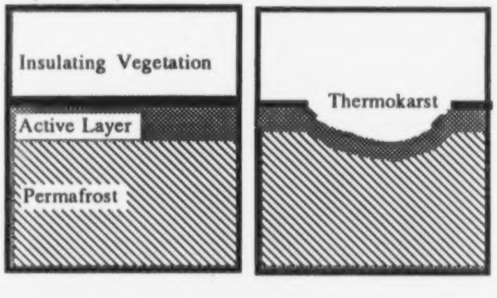


Pingos

Pingo is an Eskimo name for a cone-shaped hill or mound of soil with a core of ice. A pingo may be a few feet to 230 feet (1 to 70 m) high and up to 2000 feet (600 m) in diameter. Pingos occur in areas of both continuous and discontinuous permafrost regions of Alaska. There are two types of pingos--open systems and closed system. Closed system pingos are the most common type in tundra areas.

Closed-system pingos form after drainage or sedimentation of a tundra lake. The wet soil underlying a deep tundra lake remains unfrozen year-round since the overlying water retains heat and insulates the soil during winter. However, when a lake is drained, or it partially fills up with sediments so that thewater is no longer deep, the surface layer of soil on the lake bottom slowly freezes over. This new layer of frozen soil, along with underlying and surrounding permafrost traps water in underlying, but still unfrozen soil. As permafrost slowly advances around the trapped, unfrozen core, the water in the soil is forced inward through soil pores by pressure. When the trapped water itself freezes, it expands in the only direction possible--upward. This creates a hill or mound. The size of the pingo formed depends upon the amount of trapped water. Pingos may also form when water is trapped under permafrost ground in other ways.

Pingos may form and grow by as much as 5 feet (1.5 m) per year, and continue to grow slowly [1to 1 1/2 feet (0.3-0.5 m) per year] for 1000's of years. When the vegetation on top of a pingo is disturbed, or pressure from the expanding ice itself cracks the surface soil, the ice core is exposed to air, and warm summer temperatures. If the exposed ice melts, the top of the pingo collapses, creating a crater. The crater may or may not contain a lake.



Thermokarst development caused by the removal of insulating vegetation.

Thermokarst

Frozen water takes up more room than liquid water. Thus, when permafrost in water-filled soil melts, the remaining wet soil takes up much less room than it did when frozen. This creates a surface depression, or thermokarst. Thermokarsts may be pits, funnel-shaped sink-holes, valleys, ravines, or in early stages of melting, caves. Permafrost melting is caused by removal of surface vegetation (by fire or human activities), flooding with water, and warming of the climate.

Photo by Tom Osterkamp

Solifluction or Gelifluction

Little water can seep into permafrost soil. Thus the water from rain, snow melt, or melting of ice buried in the surface soil, is trapped in the active layer of soil. On sloping land, the weight of the water-saturated soil, combined with the effects of the water on soil properties, causes the active layer to slide, or slump downhill when thawed in summer. The rate of movement depends upon the slope, vegetative cover, and other factors, but can vary from a few centimeters per year to landslide like movements.

Photo by Bud Lehnhausen

Sorted Rock Piles and Frost Boils

In soils containing rocks, the forces created by seasonal freezing and thawing of the soil move and sometimes sort soil particles. The exact processes that cause this are still debated, and likely vary, but clearly differential rates of freezing, and the forces of expansion, contraction, and gravity are involved. Frost action first pushes large particles or stones to the soil surface, creating lines, nets, circles, or polygons of rocks. When these formations occur in soil with water-filled, fine grained soil, the expansion and contraction of this soil tends to move surface stones laterally across the ground, thus creating sorted nets, circles, and polygons rimmed by large and medium sized stones, and with centers of fine, silt or clay material.

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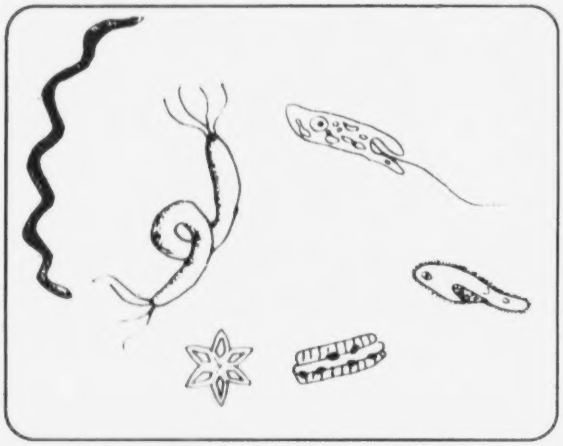
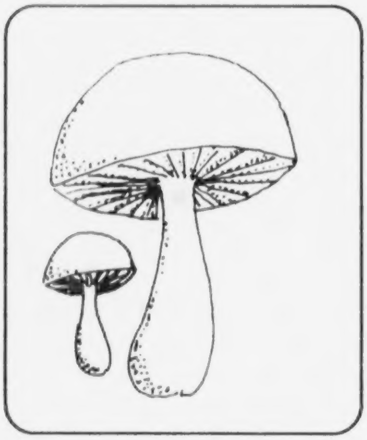
Microscopic Organisms and Fungi of Tundra Ecosystems

MONERANS AND PROTISTS OF TUNDRA: Microscopic organisms like bacteria, algae, and protozoans perform critical functions in all ecosystems. These organisms are not as abundant in tundra as in milder environments. However, millions occur in every tablespoon of soil near the tundra surface, and they are still important. Algaes are abundant in wet tundra areas, but other kinds of microscopic organisms are more numerous in moist or dry sites. Some microscopic organisms convert nitrogen from the air into a form plants can use, some photosynthesize, thus producing food for other organisms, and some causes diseases of plants, animals or other organisms. Perhaps their most important role is in breaking down dead plant and animal material. Cold temperatures, lack of oxygen (in waterlogged soil), and acidic conditions slow the decompostion activities of micro-organisms, including bacteria. The thick layers of peat (partially decayed organic material) in poorly-drained sites result from the slow rates of bacterial decomposition in tundra.



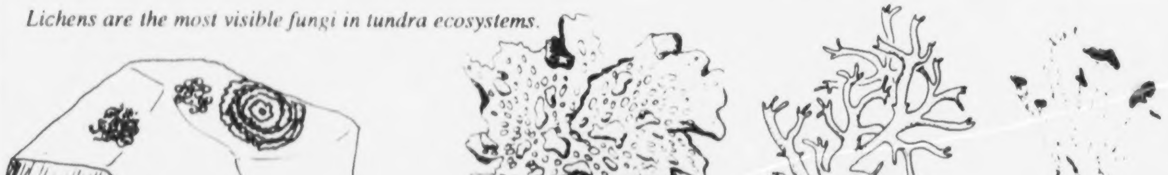
Microscopic organisms are abundant and important in all ecosystems, including tundra.

TUNDRA FUNGI: Many kinds of mushrooms, molds, and other fungi (including many microscopic forms) are present in tundra ecosystems. Many aquatic fungi occur in wet lowland tundra. In tundra, fungi are more important as decomposers than bacteria. Some fungi form mycorrhizal associations with tundra plants; these fungi help the plant obtain needed minerals from the soil in exchange for sugars produced by the plant. Lichens, the most noticeable fungi in tundra, are actually an association between a fungus and an algae. Lichens are most abundant on dry sites such as alpine tundra ridges, on frost boils, or on the tops of high center polygons in lowland tundra.

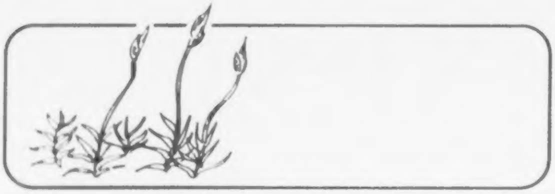


Mushrooms are the fruiting, or reproductive parts, of certain fungi. Tiny hair-like structures, called hyphae, are the main body of most fungi.

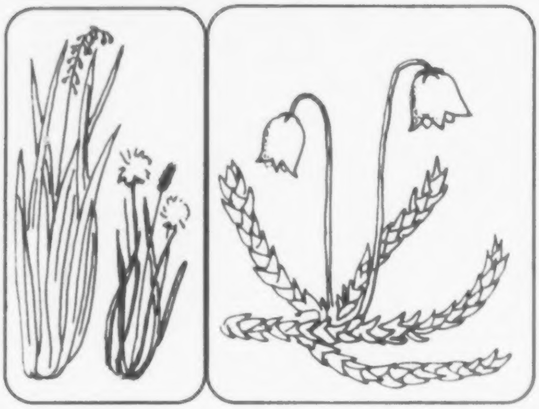
Lichens are the most visible fungi in tundra ecosystems.



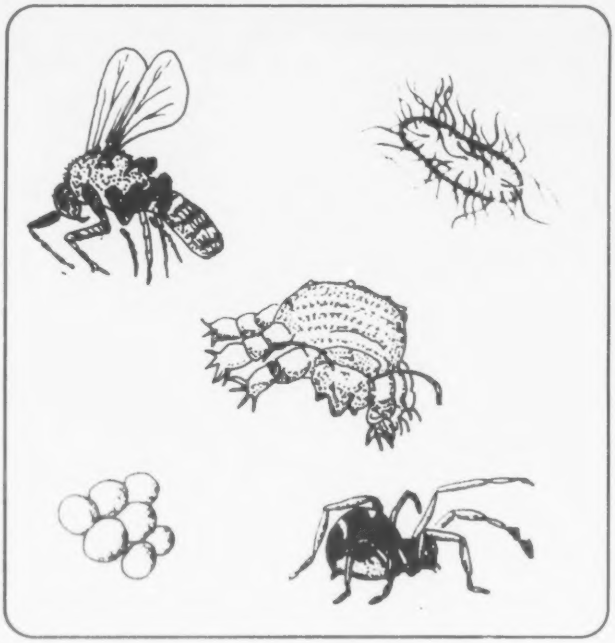
Plants and Invertebrate Animals of Tundra Ecosystems



Mosses are abundant in tundra ecosystems.



Grasses and sedges dominate wet tundra sites. Small woody plants in the heath family, such as heather, dominate dry tundra sites.



During summer, the air and the soil of tundra ecosystems are full of insects and other invertebrates.

PLANTS OF TUNDRA: Although trees are conspicuously absent from tundra ecosystems, over 300 species of other kinds of plants occur in Alaska's tundra ecosystems. Most tundra plants grow only a few inches high; though willows, the tallest shrubs, grow to more than 6 feet (1.8 m) in sites where deep snowdrifts protect them from winter. Mosses are very abundant plants in tundra ecosystems. Grasses and sedges are the most important vascular plants in wet tundra, while small woody shrubs in the heath family are dominant on dry sites in both alpine and lowland tundra. Only about 3 months per year are suitable for plant growth in most tundra areas, so most plants require many years to grow and store enough energy and minerals to reproduce. Almost all tundra plants are perennial and are able to reproduce by root sprouts, runners, or other vegetative means, as well as sexually (by seeds). Thus most tundra plants live for a long time. One rhododendron, a small, woody tundra plant, had lived 300 years when scientists counted its annual rings. Even non-woody tundra plants are thought to live for several decades.

Tundra invertebrates are only active and only apparent during the summer. During this season, flying insects such as bumblebees, ichneumonid wasps, moths, butterflies, craneflies, and midges are conspicuous. Mosquitoes and various biting flies occur in almost horrifying abundance! Other kinds of invertebrates are present, but more careful searching is required to see them. Sawflies, aphids, rove beetles, carrion beetles, and ground beetles are among the insects that live on plants or in the moss. Spiders and centipedes are also present. The greatest number and variety of invertebrates in tundra occur in the moss and upper few inches of soil. Even in the high arctic tundra near Barrow, Alaska, scientists found the following in an area of 0.9 sq yd (1 sq meter): 50,000 to 5 million nematodes, 10,000-100,000 enchytraeid worms, 10,000 to 80,000 mites, 24,000 to one half million springtails, 40,000 rotifers, 15,000 tardigrades, 700 fungus gnat larvae, and smaller numbers of other insect larvae. Nearly all of these lived within 2 inches (5 cm) of the soil surface! These soil-dwelling invertebrates feed on dead organic material, bacteria, protozoans, and each other.

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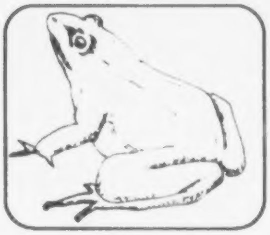
Vertebrate Animals of Tundra Ecosystems

No reptiles occur in tundra ecosystems, but one amphibian, the wood frog, occurs in tundra in many parts of Alaska.

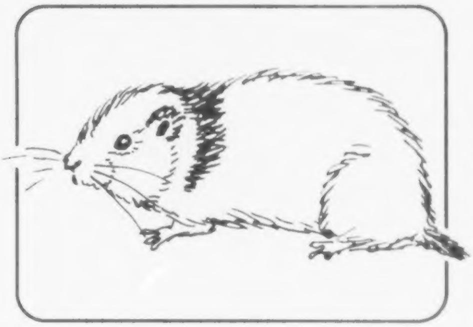


Reptiles are the only major group of vertebrate animals absent from tundra ecosystems. A single species of amphibian, the wood frog, occurs in tundra areas throughout most of Alaska, but has not been found in the far north.

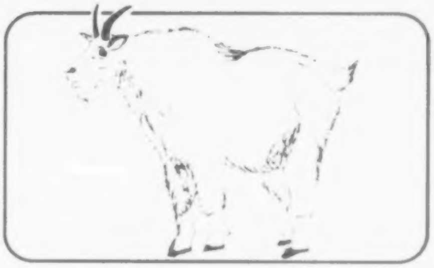
A variety of mammals occur in both alpine and lowland tundra, including shrews, lemmings, voles, arctic ground squirrels, mink, weasels, wolverines, red foxes, wolves, brown bears, and caribou. Pikas, marmots, Dall sheep, and mountain goats live mainly in alpine tundra. Muskoxen, tundra hares, and arctic foxes occur mainly in lowland tundra. Several species occur in tundra, but only in certain parts of Alaska. For example, mountain goats occur in alpine tundra only in southcoastal Alaska. River otters, muskrats, and beavers are abundant in lowland tundra of western Alaska, but are absent from tundra on the north slope.

The only birds that remain in tundra environments year-round are ravens, snowy owls, gyrfalcons, 3 species of ptarmigan, and snow buntings; even these species move out of the areas where winter conditions are most severe. During summer, over 80 species of migratory birds nest in tundra. Bird species that feed and nest in dry sites on the tundra (certain sandpipers, plovers, longspurs, and snow buntings) occur in both alpine and lowland sites. Lowland tundra also provides extremely important habitat for millions of waterbirds, including loons, swans, geese, ducks, and shorebirds.

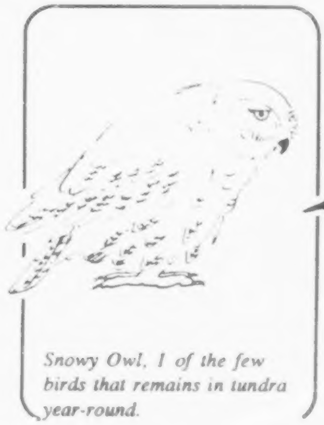
Most tundra lakes, ponds, and even rivers freeze solid during winter. However, several kinds of fish survive in tundra by migrating to deep lakes and/or deep holes in rivers that do not freeze solid in winter. Arctic charr, grayling, whitefish, ciscos, lake trout, blackfish, three-spine and nine-spine sticklebacks, burbot, and slimy sculpins are among the most common fish in tundra waters.



Lemmings are an important species in both alpine and lowland tundra.

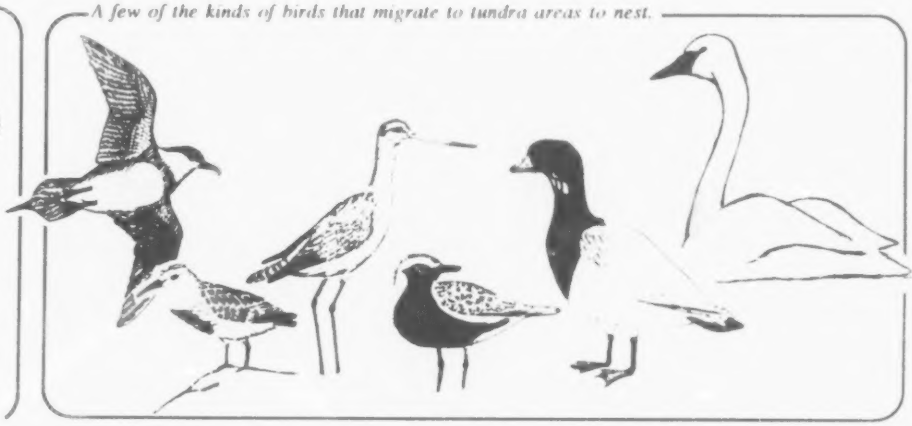


Mountain goats occur mainly in alpine tundra in coastal areas of southern Alaska.



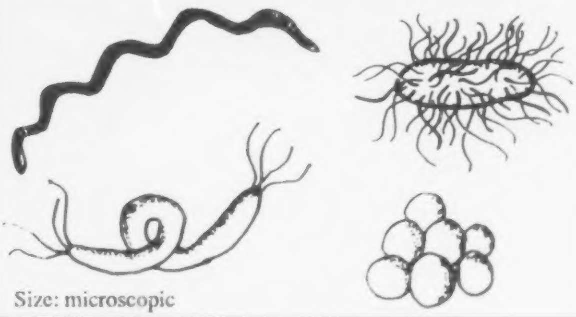
Snowy Owl, 1 of the few birds that remains in tundra year-round.

A few of the kinds of birds that migrate to tundra areas to nest.



Few birds occur in tundra during winter, but millions of birds fly thousands of miles to nest in tundra areas. Lowland tundra is extremely important as a nesting area for waterfowl, shorebirds, and other waterbirds.

Bacteria

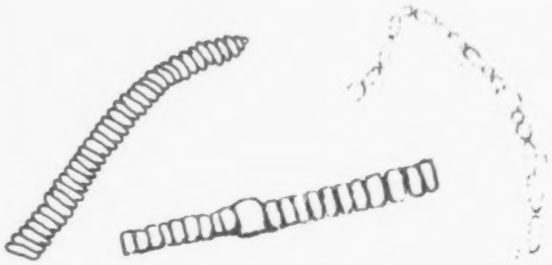


Size: microscopic

Bacteria **Protist**

HABITAT: some types of bacteria occur in every moist environment; a tablespoon of tundra soil may contain 1 billion or more bacteria
FOODS: mainly dead plant, fungi, and animal materials; some kinds of bacteria live as parasites of living things, and some are able to make their own food
EATEN BY: protozoans, some fungi
SYMBIOSES: some bacteria are parasites and cause diseases of plants, animals, or fungi; others live in the digestive tracts of animals and aid in digestion
ADAPTATIONS: bacteria can survive long periods of inactivity and unfavorable conditions

Cyanobacteria

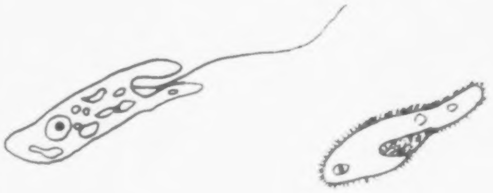


Size: microscopic to filaments visible to the naked eye

Cyanobacteria **Moneran**

HABITAT: standing water, wet rocks, moss, or logs
FOODS: most can make their own food through photosynthesis
EATEN BY: protozoans, springtails
SYMBIOSES: some cyanobacteria join with fungi to form lichens
ADAPTATIONS: lichens are able to survive very long periods of unfavorable conditions by becoming dormant; some specimens revived after 100 years of dormancy

Protozoans

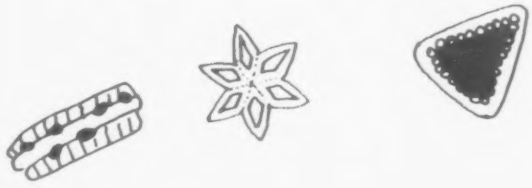


Size: microscopic

Protozoans **Protists**

HABITAT: in water, droplets of water on leaves, litter, under rocks, and in soil
FOODS: varies by species; many eat dead plant material and animal wastes; others feed on bacteria, cyanobacteria, algae, or other protozoans
EATEN BY: protozoans, roundworms, segmented worms
SYMBIOSES: some live in the intestines of certain animals and aid them in digestion of foods; many are parasites of animals
ADAPTATIONS: most are able to survive long periods of dormancy

Algae



Size: microscopic to filaments visible to naked eye

Algae **Protists**

HABITAT: in water or films of water on soil, rocks, or logs
FOODS: most algae are able to make their own food through photosynthesis
EATEN BY: protozoans, roundworms, segmented worms, springtails, mites, and certain insects
SYMBIOSES: some algae join with fungi to form lichens
ADAPTATIONS: lichens are able to survive exposure to very severe environmental conditons.

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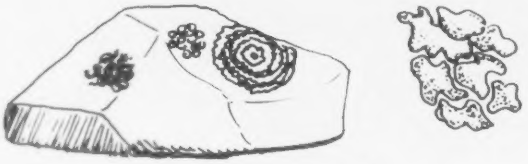
Crustose Lichens

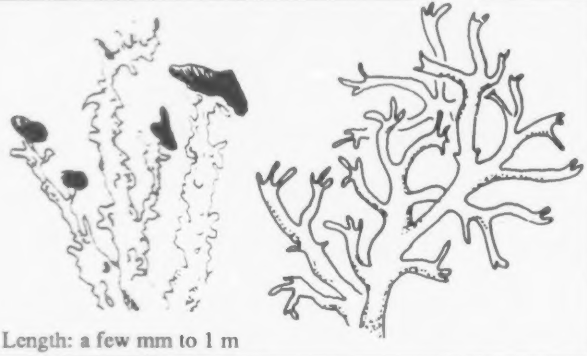


Size: 1-2 mm thick, but forming crusts up to 50 cm in diameter

Crustose Lichens **Fungi**

HABITAT: forms a crust on rocks, bones, etc.
FOODS: lichens make their own food
EATEN BY: mites, nematodes
SYMBIOSES: lichens are made up of two different organisms, an algae (protist) or cyanobacteria (moneran) and a fungi; the algae or cyanobacteria capture energy through photosynthesis while the fungi provide a protective shell; the fungi may also help absorb nutrients from rainwater or the surroundings
ADAPTATIONS: lichens are able to survive very long periods of unfavorable conditions by becoming dormant; some specimens revived after 100 years of dormancy

Fruticose Lichens

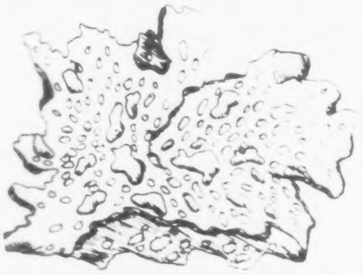


Length: a few mm to 1 m

Fruticose Lichens **Fungi**

HABITAT: grows on dry or moist ground and in trees
FOODS: lichens make their own food
EATEN BY: caribou, lemmings, mites, nematodes
SYMBIOSES: lichens are made up of two different organisms, an algae (protist) or cyanobacteria (moneran) and a fungi; the algae or cyanobacteria capture energy through photosynthesis while the fungi provide a protective shell; the fungi may also help absorb nutrients from rainwater or the surroundings
ADAPTATIONS: lichens are able to survive very long periods of unfavorable conditions by becoming dormant; some specimens revived after 100 years of dormancy

Foliose Lichens

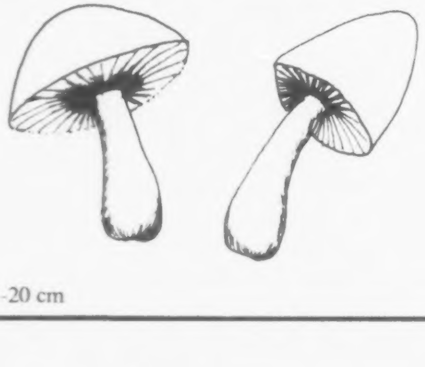


Size: 1-2 mm thick, but forming lobes up to 10 cm in diameter

Foliose Lichens **Fungi**

HABITAT: grows on moist soil and in trees
FOODS: lichens make their own food
EATEN BY: caribou, lemmings, mites, nematodes
SYMBIOSES: lichens are made up of two different organisms, an algae (protist) or cyanobacteria (moneran) and a fungi; the algae or cyanobacteria capture energy through photosynthesis while the fungi provide a protective shell; the fungi may also help absorb nutrients from rainwater or the surroundings
ADAPTATIONS: lichens are able to survive very long periods of unfavorable conditions by becoming dormant; some specimens revived after 100 years of dormancy

Gilled Mushrooms

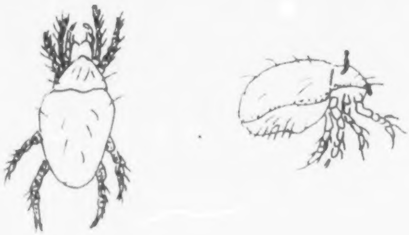


Size: 1-20 cm

Gilled Mushrooms *Basidiomycetes* **Fungi**

HABITAT: soil and dead vegetation
FOODS: mainly dead plant material and animal wastes
EATEN BY: lemmings, ground squirrels, fungi gnats
SYMBIOSES: some of the gilled mushrooms form symbiotic associations with certain plants; they receive sugar from the plant and help it obtain nutrients from the soil
ADAPTATIONS: most fungi that occur in tundra areas are able to grow at colder temperatures than those that occur in other environments

Mites

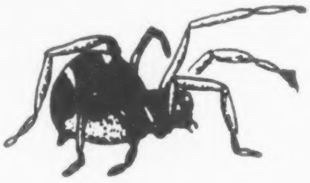


Length: microscopic to 2 mm

Mites *Order: Acarina* **Animal**

HABITAT: these tiny animals are extremely abundant in mosses, dead leaves, and soil of tundra and other habitats (10,000-83,000 occur in a square meter of tundra--greater densities occur in other habitats)
FOODS: varies by species; many prey on roundworms, other mites, and insect larvae (such as spring tails, rove beetles, and flies); others feed on plants, or on dead plants and animals
EATEN BY: ground beetles, wagtails, wheatears, longspurs, and other insect-eating birds
SYMBIOSES: unknown
ADAPTATIONS: unknown

Spiders

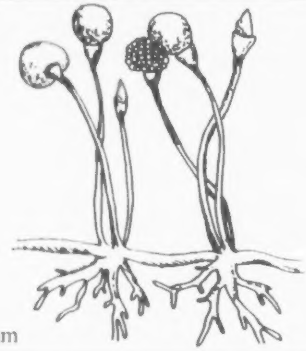


Length: 0.05-10 mm

Spiders *Order: Araneae* **Animal**

HABITAT: in and on soil or leaf litter, mosses, or lichens
FOODS: all spiders are predators on small animals, mainly insects, including aphids, flies, rove beetles, springtails, and others
EATEN BY: shrews, insect-eating birds such as plovers, sandpipers, longspurs, finches, pipits, wagtails, redpolls
SYMBIOSES: unknown
ADAPTATIONS: most tundra spiders avoid the wind by living on or in the leaf litter; the web-spinning species make horizontal or cup-shaped webs that are sheltered by surrounding vegetation

Molds, Mildews, and Rusts

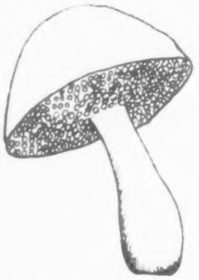


Size: microscopic to a few mm

Molds, Mildews, and Rusts *Ascomycetes* **Fungi**

HABITAT: dead plants or waste materials, or on living plants or insects
FOOD: many feed on dead plant materials, while others live as parasites on plants or insects
EATEN BY: springtails, bacteria
SYMBIOSES: some are parasites of plants and cause abnormal growth such as galls
ADAPTATIONS: their ability to cease functioning, then resume activities when conditions are favorable allow them to survive in harsh environments

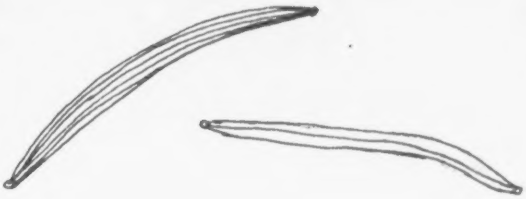
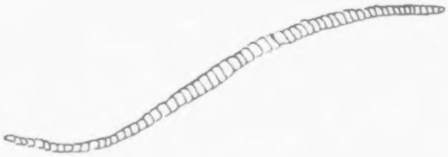
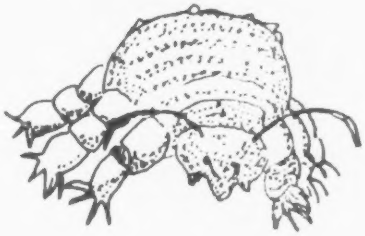
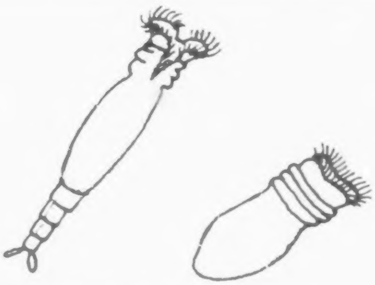
Bolete Mushrooms



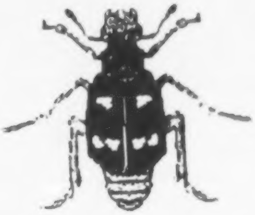
Size: 1-30 cm

Bolete Mushrooms *Basidiomycetes* **Fungi**

HABITAT: soil and litter of tundra and other habitats
FOODS: dead plant material
EATEN BY: squirrels, lemmings, fungus gnats, nematodes
SYMBIOSES: some bolete mushrooms form symbiotic associations with plants; they help the plant obtain nutrients from the soil in exchange for sugars the plant produces
ADAPTATIONS: most tundra fungi are able to grow at colder temperatures than fungi from other environments

Roundworms	**Roundworms** *Order: Nematoda* **Animal**
 Length: microscopic to 1 mm	HABITAT: various species live in the soil, on mosses, lichens, leaves, or waste materials; many live in water FOODS: varies by species; some feed on algae and bacteria; others are parasites of plants and feed on their fluids; some are parasites on large animals; some prey on small animals; others feed on waste materials EATEN BY: fish, beetles, shrews SYMBIOSES: many are parasites of plants and animals; some hitch rides to new areas on the legs of flies, beetles, birds, or mammals ADAPTATIONS: able to develop slowly and resume development after long periods of cold and inactivity
Segmented Worms	**Segmented Worms** *Family: Enchytraeidae* **Animal**
 Length: 5-10 mm	HABITAT: moist soil, mosses, or decaying plants FOODS: decaying plants, fungi, algae, or other invertebrate animals EATEN BY: ground beetles, insect-eating birds SYMBIOSES: some segmented worms, called leeches, are parasites on other animals, including mammals, fish, birds, insects, snails, and worms ADAPTATIONS: able to develop slowly and resume development after long periods of cold and inactivity
Water Bears (Tardigrades)	**Water Bears** *Phylum: Tardigrada* **Animal**
 Length: microscopic to 0.05 mm	HABITAT: these tiny animals live in the water film around mosses and lichens; they are extremely numerous in tundra areas FOODS: fluids from mosses and lichens EATEN BY: dragonflies, fish, phalaropes, sandpipers, and other insect-eating birds SYMBIOSES: unknown ADAPTATIONS: these animals have an amazing ability to survive long periods of inactivity and unfavorable environmental conditions; some species have survived 7 years of anabiosis (dormancy), and others have lived even after exposure to temperatures of -272° C
Rotifers	**Rotifers** *Phylum: Rotifera* **Animal**
 Length: microscopic to 3 mm	HABITAT: freshwater, and in or on mosses or other plants, or on lichens FOODS: aquatic species feed mainly on detritus (dead organic matter) while those that live on mosses feed on protozoans, or other small animals such as other rotifers or tardigrades EATEN BY: roundworms SYMBIOSES: unknown ADAPTATIONS: terrestrial rotifers can withstand severe environmental conditions; they are known to be able to survive 3-4 years of dormancy, and have survived after exposure to temperatures of -272° C

Carrion Beetles

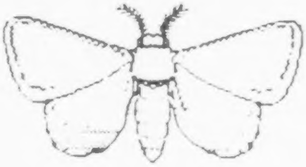


Length: 29-50 cm Weight: 0.5-1.1 kg

Carrion Beetles *Family: Silphidae* **Animal**

HABITAT: soil and litter of tundra and other habitats
FOODS: they feed on dead animals, and on other insects that feed on dead animals (such as fly larvae); the adult female lays her eggs and buries them with a dead animal
EATEN BY: plovers, sandpipers, longspurs, buntings, redpolls, wagtails, pipits, shrews
SYMBIOSES: most carrion beetles have mites riding on their backs; these mites get a free ride to a new food source but do not affect the beetle
ADAPTATIONS: unknown

Moths

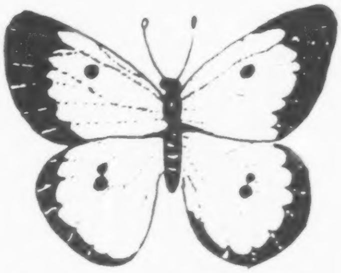


Length: 6-150 mm

Moths *Order: Lepidoptera* **Animal**

HABITAT: adults use a variety of habitats; most larvae can only live on a particular species of plant
FOODS: adults feed mainly on flower nectar; most larvae feed on plant leaves, fruits, stems, or roots
EATEN BY: shrews, and insect-eating birds, such as plovers, buntings, longspurs, wagtails, pipits, redpolls
SYMBIOSES: adults pollinate flowers; larvae are parasitized by ichneumon wasps
ADAPTATIONS: many tundra moths have dark wings, and orient themselves so their wings absorb heat from the sun

Butterflies

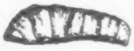


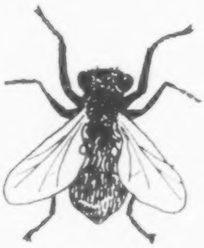
Length: 6-150 mm

Butterflies *Order: Lepidoptera* **Animal**

HABITAT: adults use a vareity of habitats; most larvae can live only on a single species of plant
FOODS: adults feed mainly on flower nectar; larvae feed on plant leaves, fruits, stems, or roots
EATEN BY: shrews, and insect-eating birds, such as plovers, buntings, longspurs, wagtails, pipits, redpolls
SYMBIOSES: adults pollinate flowers; larvae are often parasitized by ichneumon wasps
ADAPTATIONS: many tundra butterflies have dark wings and orient themselves so their wings absorb heat from the sun; tundra butterflies develop more slowly than those of other habitats; they can cease then resume development as environmental conditions change

Bot and Warble Flies

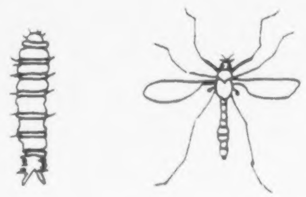
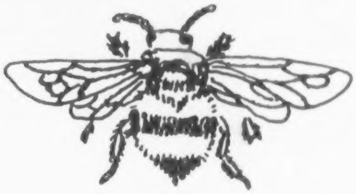
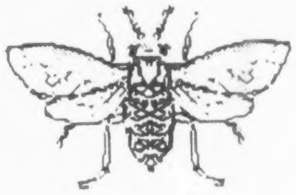
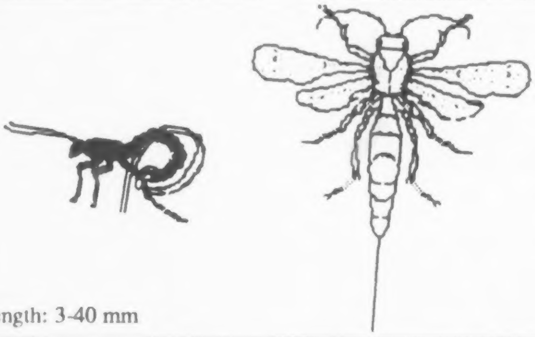




Length: 10-14 mm

Bot and Warble Flies *Order: Diptera* **Animal**

HABITAT: adults occur on the tundra; larvae develop inside an animal host
FOODS: larvae feed on the body fluids or tissues of their hosts (hares, squirrels, caribou, marmots, and other mammals); foods of the adults are unknown
EATEN BY: insect-eating birds
SYMBIOSES: bot flies lay their eggs on their host's skin; the larvae burrow under the skin and feed on tissues or body fluids of the host, then emerge and drop to the ground where they develop into adults
ADAPTATIONS: by living under the skin of large animals, bot flies avoid the cold and wind

Midges	**Midges** *Family: Chironomidae* **Animal**
 Length: 2-7.5 mm	HABITAT: larvae live in water or wet moss; adults occur in swarms over these habitats FOODS: varies by species; some larvae feed on algae and plant material; others filter microscopic organisms from the water, while still others prey on other insects; some adults feed on flower nectar and pollen EATEN BY: phalaropes, plovers, sandpipers, ducks, and other insect-eating birds; shrews, ground beetles, SYMBIOSES: midges are important pollinators of flowers in alpine and lowland tundra ADAPTATIONS: unknown
Bumblebees	**Bumblebees** *Order: Apidae* **Animal**
 Length: 8-23 mm	HABITAT: any area with nectar-producing flowers including alpine and lowland tundra; nests in the ground FOODS: nectar and pollen of flowering plants EATEN BY: shrews, and insect-eating birds, such as plovers, buntings, longspurs, wagtails, pipits, redpolls SYMBIOSES: bees are important plant pollinators; some species eat the nectar and pollen only from certain plants, thus pollinating only one species of plant; mites often hitch rides on bees to reach new plants ADAPTATIONS: the dense fur-like hair covering the bodies of bumblebees allows them to retain some of the heat generated by their muscles; thus they can remain active at colder temperatures than other insects
Sawfly Wasps	**Sawfly Wasps** *Suborder: Symphyta* **Animal**
 Length: 5-15 mm	HABITAT: adults use a variety of habitats; most larvae can live only on a single species of plant; larvae overwinter in leaf litter FOODS: mainly leaves of willows, dwarf birch, and other shrubs (or trees in forested areas); larvae of some species are leaf miners. Some species eat nectar or pollen, and others eat small insects. EATEN BY: certain wasps, shrews, plovers, buntings, and other insect-eating birds SYMBIOSES: parasitized by wasps; also, some are parasites of willows and cause these plants to form galls ADAPTATIONS: unknown
Ichneumon Wasps	**Ichneumon Wasps** *Family: Ichneumonidae* **Animal**
 Length: 3-40 mm	HABITAT: any habitat where host insects are available FOODS: these wasps lay their eggs inside larval sawflies, butterflies, moths, bees, and spiders; when the larvae hatch, they eat their host EATEN BY: shrews, insect-eating birds, such as plovers, sandpipers, buntings, pipits, wagtails, wheatears, and others SYMBIOSES: these wasps are important parasites of immature insects ADAPTATIONS: unknown

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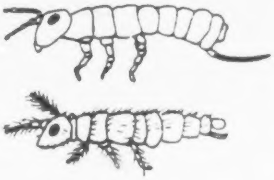
Springtails

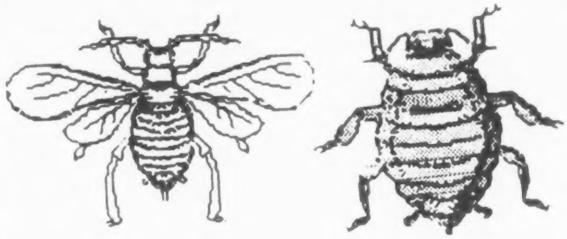


Length: up to 6 mm

Springtails *Collembola spp.* **Animal**

HABITAT: lives in soil, moss, and amid decaying plants
FOODS: decaying materials; also microscopic organisms, algae, lichens, pollen, and fungal spores
EATEN BY: centipedes, ground beetles, shrews, and insect-eating birds
SYMBIOSES: none known
ADAPTATIONS: able to develop slowly and resume development after long periods of cold and inactivity

Aphids or Plant Lice

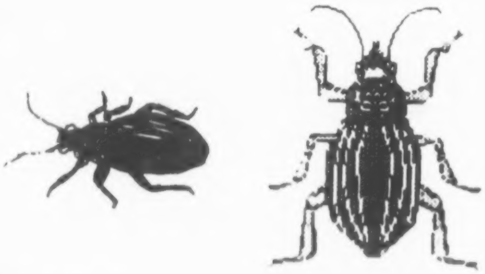


Length: 0.05-11 mm

Aphids or Plant Lice *Family Aphididae* **Animal**

HABITAT: leaves and stems of plants
FOODS: sap of plants; they cause plant leaves to wilt, curl, and turn yellow
EATEN BY: ants, wasps, longspurs, snow buntings, redpolls, pipits, larks
SYMBIOSES: aphids produce a secretion, called honeydew; in order to obtain this energy-rich honeydew, certain ants protect and tend aphids; some aphids carry microscopic organisms that cause plant diseases; some aphids cause plants to form galls
ADAPTATIONS: unknown

Ground Beetles

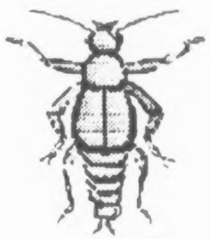


Length: 5-35 mm

Ground Beetles *Family: Carabidae* **Animal**

HABITAT: occur in most land habitats; most are active only at night, and hide during the day under rocks or dead plants
FOODS: varies by species; some adults feed on dead animal remains; others prey on insects (such as caterpillars), or on slugs and snails
EATEN BY: shrews, plovers, sandpipers, pipits, wagtails, longspurs, snow buntings, redpolls
SYMBIOSES: unknown
ADAPTATIONS: tundra species produce antifreezes that allow them to survive freezing temperatures

Rove Beetles

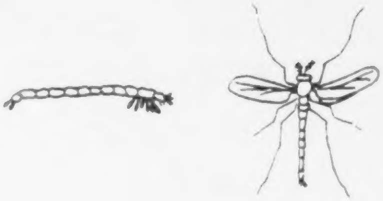


Length: 3-15 mm

Rove Beetles *Family: Staphylinidae* **Animal**

HABITAT: lives in soil and dead vegetation
FOODS: varies by species; most adults feed on dead animal or plant remains; others prey on insects
EATEN BY: plovers, sandpipers, pipits, wagtails, snow buntings, longspurs, redpolls, shrews, ground beetles
SYMBIOSES: some are parasites of other insects
ADAPTATIONS: unknown

Craneflies

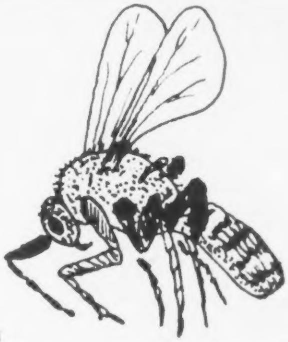


Length: 10-35 mm

Craneflies *Family: Tipulidae* **Animal**

HABITAT: varies; larvae live in moist soil, decaying plants, or in water; adults fly and occur on surrounding vegetation
FOODS: larvae feed on decaying vegetation, or in some aquatic forms, on peat; adults prey on other insects, or do not eat
EATEN BY: plovers, sandpipers, phalaropes, pipits, wagtails, buntings, longspurs, finches, loons, grebes, frogs
SYMBIOSES: some craneflies pollinate flowers
ADAPTATIONS: able to develop slowly and resume development after long periods of cold and inactivity

Fungus Gnats

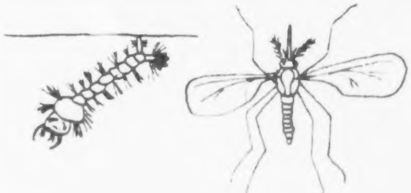


Length: 5-10 mm

Fungus Gnats *Family: Mycetophilidae and Sciaridae* **Animal**

HABITAT: moist soil, mosses, or decaying plants
FOODS: fungi, decaying plants, and roots of live plants
EATEN BY: ground beetles, spiders, insect-eating birds
SYMBIOSES: unknown
ADAPTATIONS: unknown

Mosquitos

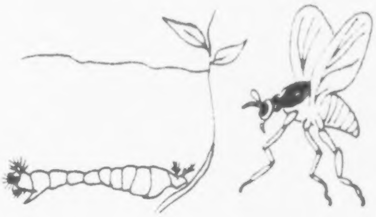


Length: 2-4.5 mm

Mosquitos *Family: Culicidae* **Animal**

HABITAT: larvae live in the water; adults are found in most habitats including tundra; males are often found in or near flowers
FOODS: larvae feed on algae, protozoans, and dead plants; adult males feed on flower nectar, while adult females suck the blood of animals
EATEN BY: dragonflies, fish, phalaropes, sandpipers, other insect-eating birds, and frogs
SYMBIOSES: males pollinate flowers; females carry microscopic, disease-causing organisms
ADAPTATIONS: unknown

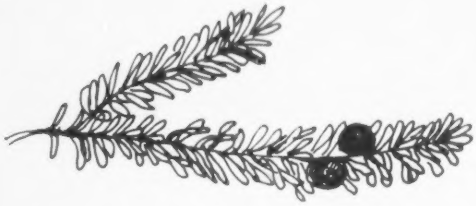
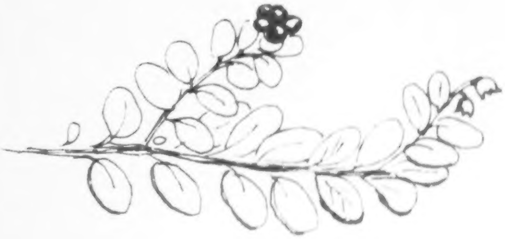
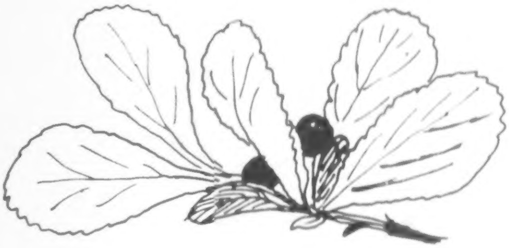
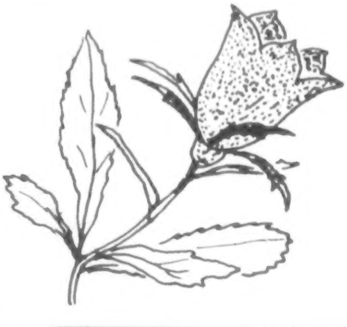
Black Flies



Length: 3-15 mm

Black Flies *Family: Simuliidae* **Animal**

HABITAT: lives in the soil and dead vegetation
FOODS: larvae live in the water and feed on algae, protozoans, and dead plant material; adults feed on flower nectar; adult females also suck blood from vertebrate animals
EATEN BY: fish, spiders, phalaropes, and other insect-eating birds
SYMBIOSES: many flies are important flower pollinators in tundra ecosystems; adults transmit microscopic organisms that cause diseases in birds
ADAPTATIONS: unknown

Crowberry	**Crowberry** *Empetrum nigrum* **Plant**
 Height: 5 cm	HABITAT: moist or wet ground in alpine and lowland tundra and boreal forest FOODS: makes its own food EATEN BY: berries are eaten by lemmings, voles, geese plovers, snow buntings, longspurs, and rosy finches SYMBIOSES: crowberry depends upon mycorrhizal fungi to help it obtain minerals from the soil; in exchange it provides sugars for the fungi ADAPTATIONS: the small, wax-coated leaves of crowberry are resistant to drying by wind and cold; the low growth form of this plant reduces its exposure to the wind; crowberry is a perennial
Lingenberry	**Lingenberry** *Vaccinium vitis-iadaea* **Plant**
 Height: 10 cm	HABITAT: moist soils in alpine and lowland tundra and boreal forest FOODS: makes its own food EATEN BY: bears, lemmings, voles, ptarmigan, geese, plovers, snow buntings, longspurs, and other seed-eating animals SYMBIOSES: these plants depend upon mycorrhizal fungi to obtain nutrients from the soil, and in exchange provide sugars for the fungi ADAPTATIONS: the small wax-coated leaves of lingenberry are resistant to drying by wind and cold; the low growth form of this plant reduces its exposure to the wind; lingenberry is a perennial
Alpine Bearberry	**Alpine Bearberry** *Vaccinium alpina* **Plant**
 Height: 6 cm	HABITAT: grows on dry and moist soil in alpine and lowland tundra FOODS: makes its own food through photosynthesis EATEN BY: bears, voles, lemmings, ptarmigan, geese, plovers SYMBIOSES: bearberry depends upon mycorrhizal fungi to help it obtain nutrients from the soil; in exchange it provides sugars to the fungi; bearberry depends upon animals to transport its seeds ADAPTATIONS: the low growth form of these plants reduces their exposure to wind; bearberry is a perennial
Harebell	**Harebell** *Campanula spp.* **Plant**
 Height: 5-15 cm	HABITAT: dry to moist soil in rock crevices of alpine tundra FOODS: makes its own EATEN BY: lemmings,voles, ground squirrels, hares SYMBIOSES: depends upon insects to pollinate its flowers ADAPTATIONS: the low growth form of these plants reduces their exposure to winds; its perennial growth allows it to survive and reproduce despite the short growing season in tundra regions; its purple, cup-shaped flowers absorb and retain heat better than light-colored flowers of other shapes.

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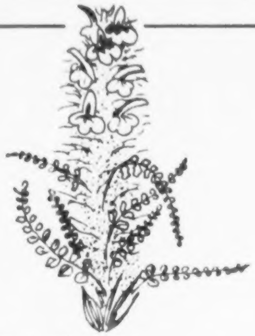
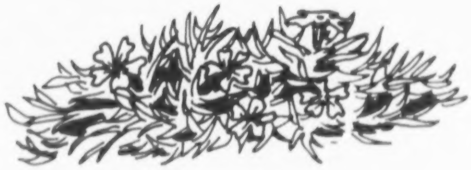
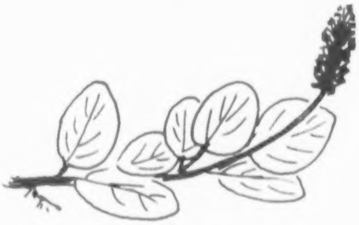
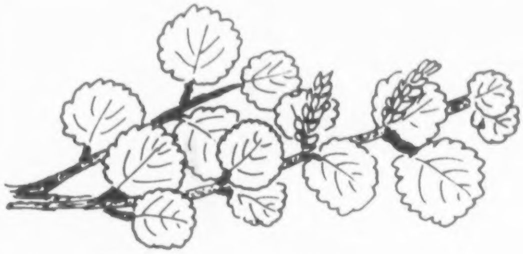
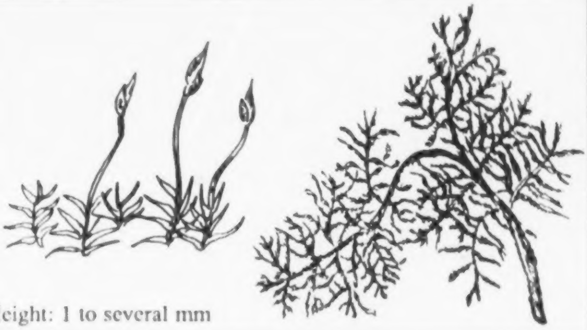
Lousewort	**Lousewort** *Pedicularis spp.* **Plant**
 Height: up to 15 cm on tundra sites	HABITAT: dry soil of alpine and lowland tundra FOODS: makes its own EATEN BY: ground squirrels, lemmings SYMBIOSES: depends upon bees to carry its pollen and provides nectar in return ADAPTATIONS: some species have dense hairs that surround their flowers; the hairs trap heat and reduce wind speed; the perennial growth and large root of this plant allows it to survive and reproduce despite the short growing season in tundra regions; the dead leaves are retained at the base of the plant and help protect the shoots and flower buds during winter
Moss Campion	**Moss Campion** *Silene acaulis* **Plant**
 Height: 5 cm	HABITAT: on dry soil in alpine and lowland tundra FOODS: makes its own EATEN BY: Dall sheep, mountain goats SYMBIOSES: depends on insects to carry its pollen ADAPTATIONS: the low-growth form and cushion shape of this plant allow it to avoid severe winds and help it retain heat; its purple flowers absorb heat from the sun; its perennial growth allows it to survive and reproduce despite the short growing season in tundra regions
Willow	**Willow** *Salix spp.* **Plant**
 Height: up to 2 m in sheltered sites	HABITAT: moist and wet sites in alpine and lowland tundra FOOD: makes its own food EATEN BY: muskoxen, caribou, ptarmigan, redpolls SYMBIOSES: depends upon mycorrhizal fungi to help it obtain minerals from the soil ADAPTATIONS: willows that grow in tundra areas have woody stems that grow along the ground, rather than upward; this allows the plant to avoid severe winds and to take advantage of the warmer temperatures near the soil; its perennial growth allows it to survive and reproduce despite the short growing season in tundra regions
Dwarf Birch	**Dwarf Birch** *Betula nana* **Plant**
 Height: up to 0.75 m	HABITAT: moist and wet alpine and lowland tundra FOODS: makes its own EATEN BY: ptarmigan, caribou, muskox, seed-eating birds such as snow buntings, longspurs, and redpolls SYMBIOSES: depends upon mycorrhizal fungi to help it obtain nutrients from the soil ADAPTATIONS: the low-growth form of this shrub allows it to avoid the wind and take advantage of warm soil temperatures; its perennial growth allows it to survive and reproduce despite the short growing season in tundra regions

Mosses

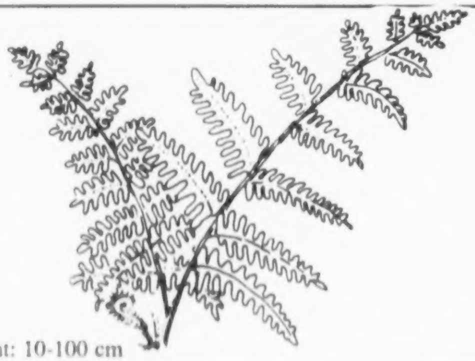


Height: 1 to several mm

Mosses *Atracheata* **Plants**

HABITAT: moist soil, rocks, or logs
FOODS: makes its own
EATEN BY: springtails, mites
SYMBIOSES: unknown
ADAPTATIONS: the ability of mosses to grow slowly and alternate periods of growth and inactivity allow them to survive in harsh environments

Ferns

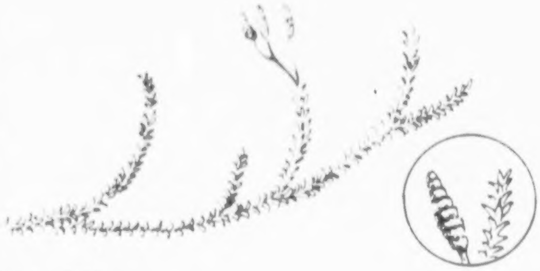


Height: 10-100 cm

Ferns *Polypodiphyta* **Plants**

HABITAT: moist habitats
FOODS: makes its own
EATEN BY: unknown
SYMBIOSES: unknown
ADAPTATIONS: unknown

Club Mosses

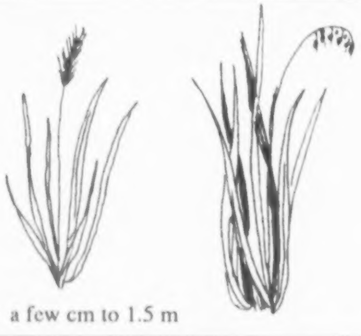


Height: 5-20 cm

Club Mosses *Lycopodiaceae* **Plant**

HABITAT: moist ground
FOOD: makes its own
EATEN BY: springtails, mites
SYMBIOSES: unknown
ADAPTATIONS: their ability to cease functioning, then resume activities when conditions are favorable allow them to survive in harsh environments

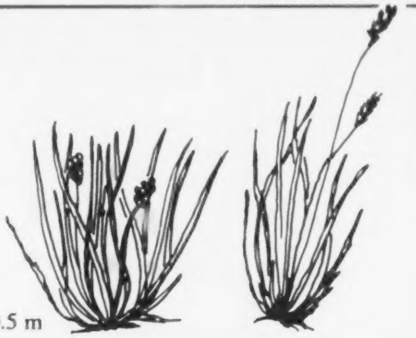
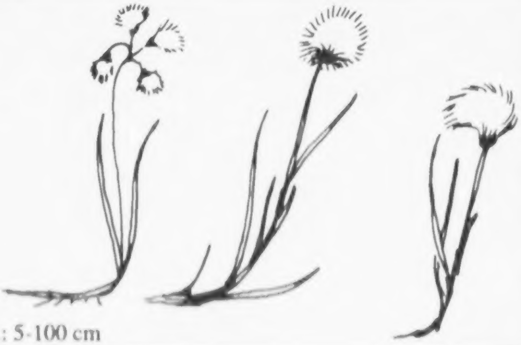
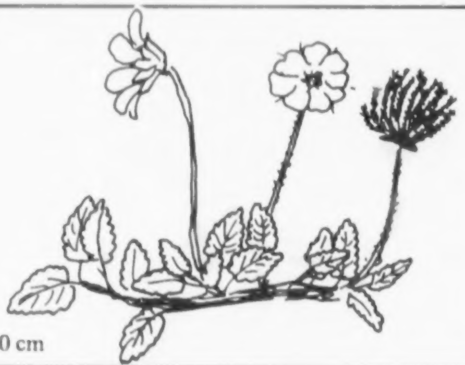
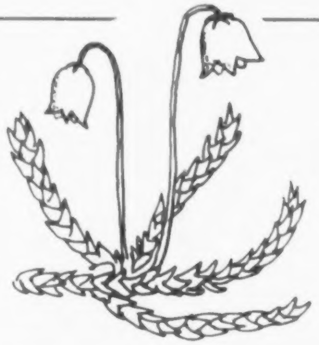
Grasses



Height: a few cm to 1.5 m

Grasses *Graminidae* **Plants**

HABITAT: wet, moist, and dry soils depending on the species
FOODS: make their own
EATEN BY: caribou, lemmings, voles, ground squirrels, marmots, goats, sheep; also, their seeds are eaten by snow buntings, longspurs, and redpolls
SYMBIOSES: grasses are parasitized by certain yeasts and other fungi; most depend upon mycorrhizal fungi to help them obtain nutrients from the soil
ADAPTATIONS: their long narrow leaf shape is less likely to be shredded or ripped by strong winds

Sedges	**Sedges** *Carex spp.* **Plant**
 Height: 5 cm to 0.5 m	HABITAT: moist or wet ground FOODS: sedges make their own food EATEN BY: caribou, muskoxen, Dall sheep, mountain goats, ground squirrels, pikas, marmots, lemmings, voles, geese; also seed-eating birds, such as snow buntings, longspurs, and rosy finches SYMBIOSES: unknown ADAPTATIONS: the long, narrow leaf shape of sedges reduces fraying by strong winds
Cottongrass	**Cottongrass** *Eriophorum spp.* **Plant**
 Height: 5-100 cm	HABITAT: this mis-named sedge grows on moist or wet ground FOODS: make their own food EATEN BY: caribou, muskox, lemmings, voles, geese SYMBIOSES: tussocks formed by cottongrass provide shelter and nest sites for small tundra birds and mammals (e.g. longspurs, lemmings) ADAPTATIONS: the cottony seeds of these plants are dispersed by the wind; the narrow leaves are less susceptible to fraying by strong winds; cottongrass is a perennial and retains its dead leaves each year; these droop and help insulate its stalks, roots, and the young shoots produced the next spring
Dryas	**Dryas** *Dryas spp.* **Plant**
 Height: 2-10 cm	HABITAT: grows on dry soil FOODS: makes its own food through photosynthesis EATEN BY: caribou, lemmings, ground squirrels SYMBIOSES: dryas plants harbor bacteria in their roots; the bacteria extract nitrogen from the air and make it available to the plant, while the plant provides sugars to feed the bacteria ADAPTATIONS: the small, leathery leaves of dryas lose less water than other kinds of leaves and are more resistant to winds; the low growth form of these plants reduces their exposure to wind; their seed heads are borne on stalks, so that the seeds can be more easily dispersed by the wind; dryas is a perennial
Heather	**Heather** *Cassiope* **Plant**
 Height: 5 cm	HABITAT: dry soil FOODS: makes its own through photosynthesis EATEN BY: lemmings, ground squirrels SYMBIOSES: depends upon insects to pollinate its flowers ADAPTATIONS: the small, leathery leaves of cassiope lose less water than other kinds of leaves and are more resistant to winds; a low growth form reduces their exposure to winds; their perennial growth allows them to survive despite the short growing seasons in tundra regions; the bell-shaped flowers retain solar heat and deflect wind from the seed-producing flower parts

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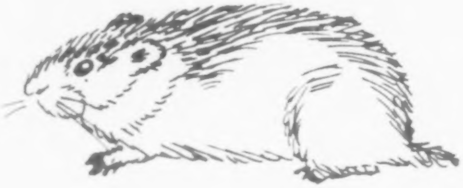
Lemmings



Length: 10-13.5 cm Weight: 30-112 gm

Lemmings *Lemmus, Dicrostonyx, and Synaptomys spp.* **Animal**

HABITAT: 4 species occur in Alaska; all occur in alpine and lowland tundra
FOODS: shoots of grasses, sedges, and other plants in summer; bark and twigs of willow and dwarf birch, and roots of various tundra plants in winter; occasionally insects, berries, and fungi
EATEN BY: owls, jaegers, gulls, arctic foxes, weasels
SYMBIOSES: parasitized by a variety of invertebrates and microscopic organisms
ADAPTATIONS: thick fur, short legs, tail, and ears; collared lemmings turn white in winter and grow shovel-like claws for digging through snow and ice

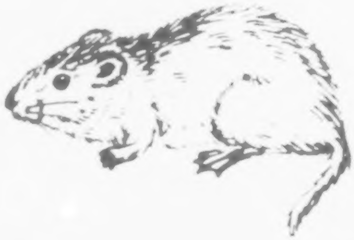
Shrews

Length: 7.5-13 cm Weight: 3-9 gm

Shrews *Sorex spp.* **Animal**

HABITAT: alpine and lowland tundra and forests throughout Alaska
FOODS: insect larvae and adults, and a variety of small invertebrate animals
EATEN BY: jaegers, weasels, foxes, owls
SYMBIOSES: parasitized by a variety of invertebrate and microscopic organisms
ADAPTATIONS: their small size allows them to live under the snow, where they remain active throughout the winter

Voles

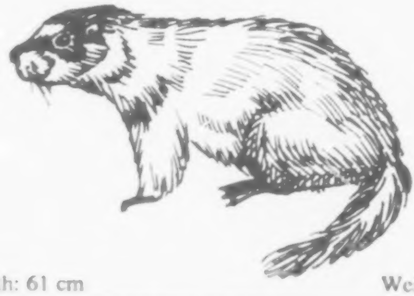


Length: 10-18 cm Weight: 28-63 gm

Voles *Microtus spp.* **Animal**

HABITAT: lowland and alpine tundra
FOODS: alpine plants including grasses, sedges, flowering herbs, and berries; also lichens
EATEN BY: weasels, foxes, owls, jaegers, hawks
SYMBIOSES: parasitized by a variety of invertebrate and microscopic organisms; by excavating the ground and carrying seeds, voles may help a variety of plants survive and spread to new tundra areas
ADAPTATIONS: some species, such as the singing vole, gather and dry large amounts of green vegetation during summer to serve as their winter food supply

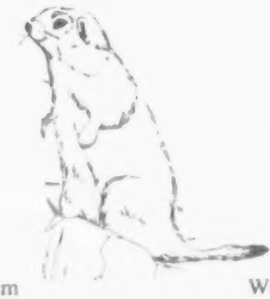
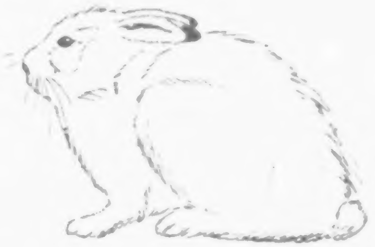
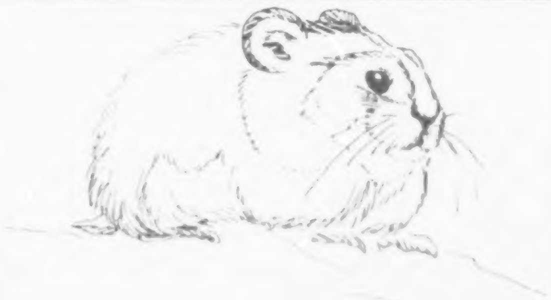
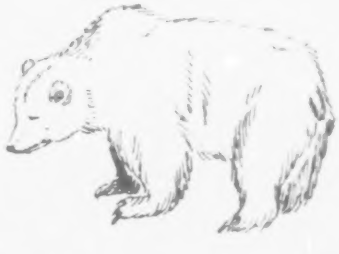
Marmots



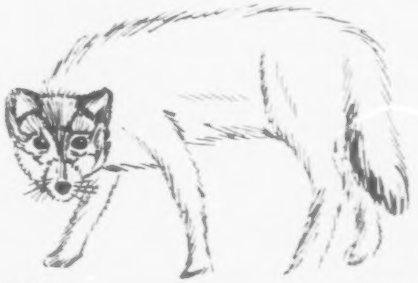
Length: 61 cm Weight: 4.5 kg

Marmots *Marmota spp.* **Animal**

HABITAT: well-drained or rocky slopes of alpine tundra throughout Alaska; the Alaska marmot occurs only in the Brooks Range, while the hoary marmot occurs elsewhere in the state
FOODS: grasses, sedges, and herbs
EATEN BY: golden eagles, brown bears, wolves
SYMBIOSES: parasitized by a variety of invertebrate and microscopic organisms
ADAPTATIONS: thick fur, hibernates in an underground den during winter; Alaska marmots (the species) hibernate in groups in communal dens, thus reducing heat loss by each individual marmot

Arctic Ground Squirrel	**Arctic Ground Squirrel** *Spermophilus parryi* **Animal**
 Length: 29-50 cm Weight: 0.5-1.1 kg	HABITAT: well-drained soil of lowland and alpine tundra FOODS: mainly shoots and leaves of tundra plants, but also berries, insect larvae, bird eggs, and carrion EATEN BY: foxes, wolves, wolverines, brown bears, golden eagles, rough-legged hawks, snowy owls SYMBIOSES: a variety of microscopic and invertebrate organisms parasitize squirrels; certain tundra plants that require nutrient-rich soil grow around the burrows of ground squirrels; squirrels help aerate and fertilize soil, and may transport seeds of certain plants ADAPTATIONS: hibernates for 7 months every year
Tundra Hare	**Tundra Hare** *Lepus othus* **Animal**
 Length: 56-71 cm Weight: 2.7-5.4 kg	HABITAT: windswept rocky slopes and dry lowland tundra of western, and parts of northern Alaska FOODS: willow shoots, and the leaves, flowers, and shoots of other tundra plants EATEN BY: wolves, snowy owls, golden eagles SYMBIOSES: a variety of invertebrate and microscopic organisms parasitize hares ADAPTATIONS: relatively short ears, dense fur, and white winter pelage; their young are covered with fur at birth and have their eyes open (in contrast to rabbits which give birth to young that lack fur and have their eyes closed)
Collared Pika	**Collared Pika** *Ochotona collaris* **Animal**
 Length: 15-21.6 cm Weight: 112-176 gm	HABITAT: rocky slopes of alpine tundra in eastern, central Alaska FOODS: mainly stems and leaves of grasses, sedges, and other alpine tundra plants EATEN BY: foxes, weasels, martens, rough-legged hawks, golden eagles, snowy owls SYMBIOSES: parasitized by a variety of invertebrate organisms, including botflies, fleas, mites, and nematodes, and various microscopic organisms ADAPTATIONS: dries and stores plants for winter food
Brown Bear	**Brown Bear** *Ursus arctos* **Animal**
 Length: 90-110 cm Weight: 147-386 kg	HABITAT: tundra and forests throughout Alaska FOODS: In spring, over-wintered berries, roots, and fresh grasses and herbs; during summer and fall, berries are important; brown bears also kill and eat small mammals, caribou, moose, salmon, and feed on carrion. EATEN BY: other brown bears SYMBIOSES: parasitized by a variety of invertebrate and microscopic organisms; brown bears help transport seeds of berry-producing plants ADAPTATIONS: brown bears survive winter by remaining dormant in an underground den

Arctic Fox

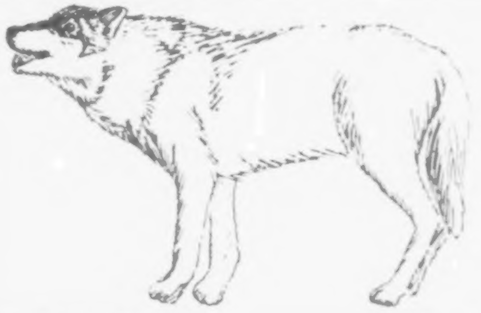


Length: 1.1 m Weight: 2.7-4.5 kg

Arctic Fox *Alopex lagopus* **Animal**

HABITAT: coastal lowland tundra of northern and western Alaska in summer; also on pack ice in winter
FOODS: mainly lemmings, but also birds, bird eggs, and carrion left by larger carnivores
EATEN BY: wolves
SYMBIOSES: arctic foxes often feed on the left-overs of animals killed by bears and wolves; a variety of microscopic and invertebrate organisms parasitize foxes
ADAPTATIONS: dense warm fur, which changes from white in winter, to brown in summer; relatively short legs and ears

Wolf

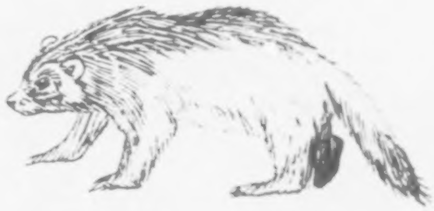


Length: 1.4-1.7 m Weight: 38-58.5 kg

Wolf *Canis lupus* **Animal**

HABITAT: alpine and lowland tundra and forests throughout Alaska
FOODS: mainly adult and young caribou, moose, sheep, or goats; but also ground squirrels, marmots, hares, lemmings, birds, and fish during summer
EATEN BY: no regular predators; occasionally other wolves
SYMBIOSES: a variety of invertebrate and microscopic organisms parasitize wolves
ADAPTATIONS: social hunting behavior allows them to prey on large ungulates

Wolverine

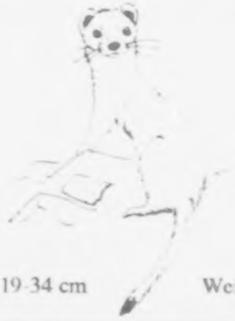


Length: 0.9-1.1 m Weight: 11-30 kg

Wolverine *Gulo gulo* **Animal**

HABITAT: alpine and lowland tundra and forests throughout Alaska
FOODS: mainly carrion, but they also kill lemmings, hares, marmots, ground squirrels, ptarmigan, grouse and calves of caribou, moose, sheep, and goats; also insect larvae, eggs, berries, fish, and carrion
EATEN BY: possibly wolves or brown bears
SYMBIOSES: parasitized by a variety of invertebrate and microscopic organisms; feeds mainly on scraps from kills of brown bears and wolves
ADAPTATIONS: dense winter fur; spine-like hairs on the pads of their feet help them walk on snow and ice

Weasel



Length: 19-34 cm Weight: Least weasel--28-63 gm
Ermine 28-168 gm

Weasel *Mustela spp.* **Animal**

HABITAT: alpine and lowland tundra and forests throughout Alaska
FOODS: mainly voles, lemmings, and shrews, but also small birds, insects, and plants
EATEN BY: snowy owls, rough-legged hawks, foxes, golden eagles
SYMBIOSES: parasitized by a variety of invertebrate and microscopic organisms
ADAPTATIONS: fur turns white in winter; small size allows them to live under the snow in winter

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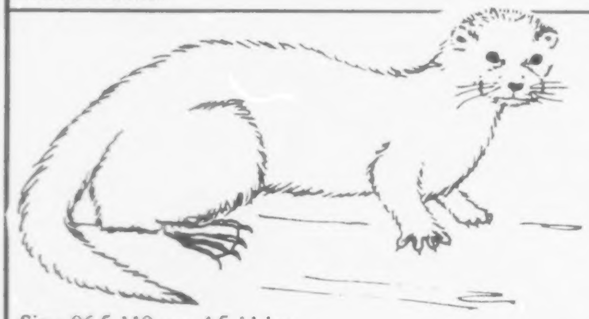
River Otter

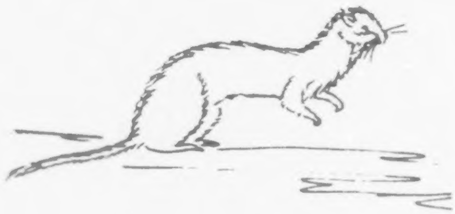


Size: 96.5-119 cm; 4.5-11 kg

River Otter *Lutra canadensis* **Animal**

HABITAT: associated with fresh water or coastal saltwater; occur throughout Alaska except Seward Peninsula and western North Slope
FOODS: mainly fish of various types; in coastal areas they also eat clams and other shellfish
EATEN BY: possibly bears and wolves
SYMBIOSES: uses ponds created by beavers; parasitized by variety of invertebrates
ADAPTATIONS: dense fur and layer of fat allows them to remain active all winter and swim in cold water

Mink

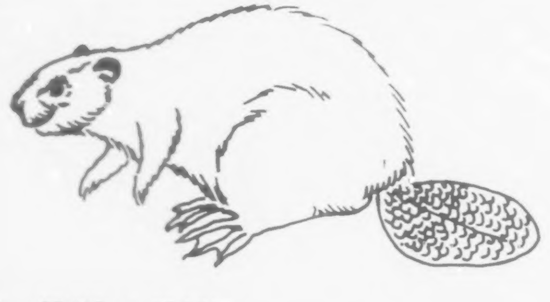


Size: 43-66 cm; 0.6-1.4 kg

Mink *Mustela vison* **Animal**

HABITAT: along streams, lakes, marshes, and coastal areas; in winter may venture into the forest away from water.
FOODS: feeds on a wide variety of small animals, including muskrats, voles, lemmings, birds and eggs, frogs, salamanders, mussels, aquatic insects, fish
EATEN BY: large predatory birds, like eagles and owls; possibly bears and wolves
SYMBIOSES: parasitized by a variety of microscopic and invertebrate organisms
ADAPTATIONS: its dense fur keeps it warm and allows it to swim even in the winter; it hunts small mammals under the snow

Beaver

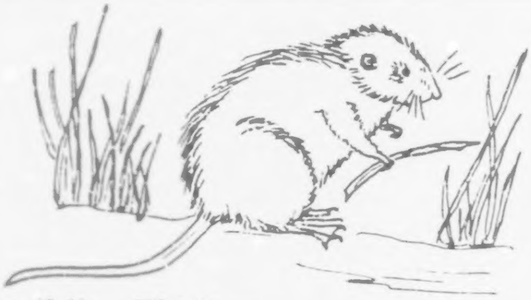


Size: 98-113 cm; 15-35 kg

Beaver *Castor canadensis* **Animal**

HABITAT: along streams, rivers, and lakes where there are adequate stands of willows, birch, or aspen for food; not found north of the Brooks Range; occurs in marshes of western Alaska and in mountain valleys throughout the rest of the state
FOODS: bark, twigs, and branches of deciduous trees like aspen, willow, birch, poplar, alder
EATEN BY: wolves, bears, possibly large predatory birds such as eagles and owls
SYMBIOSES: creates ponds used by many other animals
ADAPTATIONS: builds lodges for shelter and food storage for winter; remains active under the ice

Muskrat

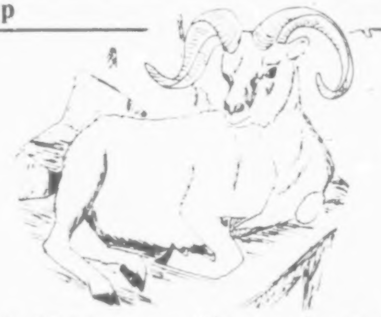


Size: 40-64 cm; 800-1600 gm

Muskrat *Ondatra zibethicus* **Animal**

HABITAT: freshwater ponds. lakes, and marshes; throughout Alaskla south of the Brooks Range
FOODS: aquatis plants, including cattails, bulrushes, water lily, and pondweed; also mussels, frogs, and fish
EATEN BY: mink, wolves, coyotes, northern pike
SYMBIOSES: feeding on aquatic plants keeps ponds from filling in as quickly
ADAPTATIONS: remains active through the winter by maintaining openings in the pond ice, called push-ups, so they can swim under the ice to get plants, but still have breathing holes and places to surface

Dall Sheep

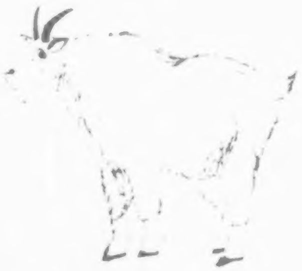


Shoulder Height: 0.9-1.1 m
Weight: males--91-113 kg
females--48-64 kg

Dall Sheep *Ovis dalli* **Animal**

HABITAT: uses separate summer and winter ranges in alpine tundra of much of Alaska; requires cliffs for escape cover, and windblown ridges where food is available during winter
FOODS: mainly alpine grasses and sedges, but also flowering herbs, willows, and mosses of alpine tundra
EATEN BY: wolves, wolverines, bears, humans, and golden eagles (lambs only)
SYMBIOSES: depends on microscopic organisms to help it digest its foods
ADAPTATIONS: white color, dense fur, sharp hooves specially designed for climbing

Mountain Goat

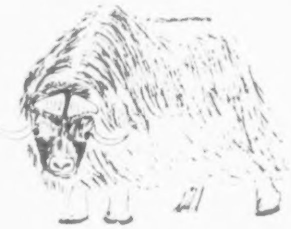


Shoulder Height: 0.9-1.1 m
Weight: 45-135 kg

Mountain Goat *Oreamnos americanus* **Animal**

HABITAT: lives on steep hillsides and cliffs of alpine tundra in southeastern and southcentral Alaska; requires cliffs for escape, and windblown ridges during winter
FOODS: grasses, herbs, and low-growing shrubs of alpine tundra in summer; hemlock, willow, and other woody plants are its main winter foods
EATEN BY: wolves, coyotes, humans, and golden eagles (lambs only)
SYMBIOSES: depends on microscopic organisms in its digestive system to help it digest its food
ADAPTATIONS: white color, long dense fur, sharply pointed and concave hooves specially designed for climbing

Muskox

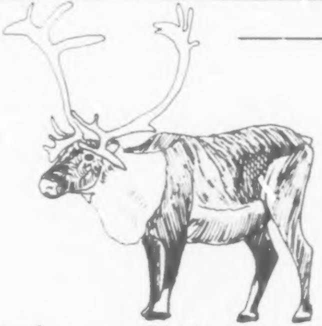


Shoulder Height: 0.9-1.5 m
Weight: males--270-360 kg
females--180-225 kg

Muskox *Ovibus moschatus* **Animal**

HABITAT: lowland tundra of northern and western Alaska; prefers floodplains and river bottoms in summer; requires windblown, snowfree areas in winter
FOODS: grasses, sedges, herbs, and woody plants such as willows
EATEN BY: wolves and humans
SYMBIOSES: depends on microscopic organisms in its digestive system to help it digest its food
ADAPTATIONS: large size, long dense fur, short legs and tail

Caribou



Shoulder Height: 1.1-1.2 m
Weight: males--158-180 kg
females--79-101 kg

Caribou *Rangifer tarandus* **Animal**

HABITAT: lowland and alpine tundra and boreal forest, mainly in northern, central, and northwestern Alaska; requires cool windblown sites or snow fields to escape summer insect harrassment
FOODS: grasses, sedges, herbs, and woody plants in summer; during winter, lichens are an important food
EATEN BY: wolves, brown bears, wolverines, humans, and (calves only) golden eagles
SYMBIOSES: depends on microscopic organisms in its digestive system to help it digest its food
ADAPTATIONS: large size, long dense fur, short tail; counter-current blood flow in legs

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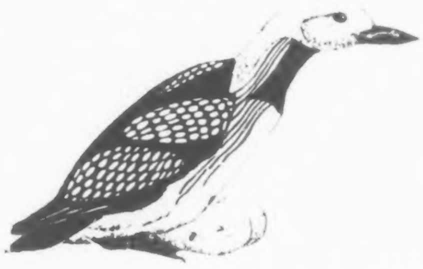
Loons

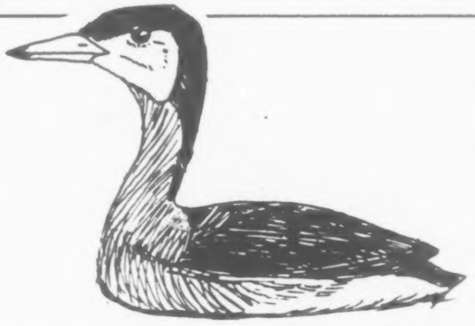


Length: 57.5-90 cm Weight: 1.8-6.8 kg

Loons *Gavia spp.* **Animal**

HABITAT: ponds and lakes in tundra and forested areas
FOODS: mainly small fish
EATEN BY: eggs and young by foxes, weasels, bears, and jaegers; young may also be taken by northern pike
SYMBIOSES: a variety of microscopic and invertebrate organisms parasitize loons
ADAPTATIONS: loons migrate from nesting areas in wetlands of northern tundra and forests, to wintering areas along the North American coast south to Mexico

Grebes

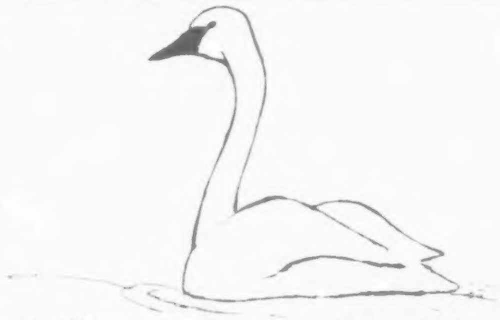


Length: 38-55 cm Weight: 0.4-0.9 kg

Grebes *Podiceps spp.* **Animal**

HABITAT: wetlands of lowland tundra, forests, and coastal areas
FOODS: mainly small fish (sticklebacks, sculpin, herring, minnows, and eels); less commonly, insect larvae and adults, crustaceans, frogs, and leeches
EATEN BY: eggs and young may be eaten by bears, foxes, falcons; young may be eaten by northern pike
SYMBIOSES: a variety of invertebrate and microscopic organisms parasitize grebes
ADAPTATIONS: migrate from tundra nesting areas to wintering areas at sea and ice-free wetlands

Tundra Swan

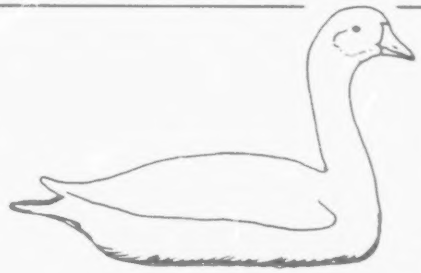


Length: 132 cm Weight: 4.7-8.1 kg

Tundra Swan *Cygnus columbianus* **Animal**

HABITAT: nests on coastal lowland tundra
FOODS: grasses, sedges, and aquatic plants
EATEN BY: eggs and young by bears, foxes; adults by humans
SYMBIOSES: parasitized by a variety of invertebrate and microscopic organisms
ADAPTATIONS: migrates from tundra nesting areas, to southern lakes and coastal wetlands for winter

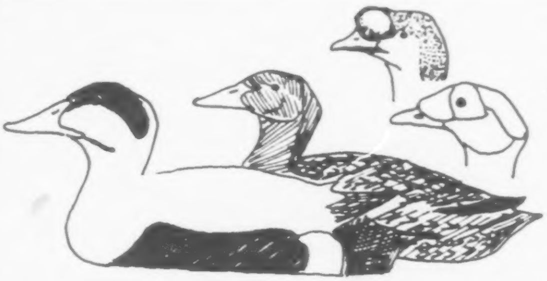
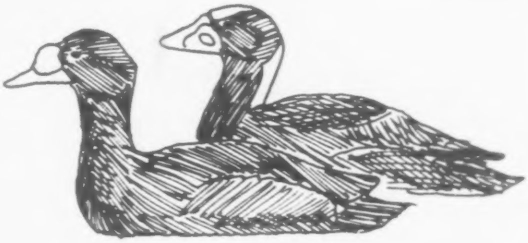
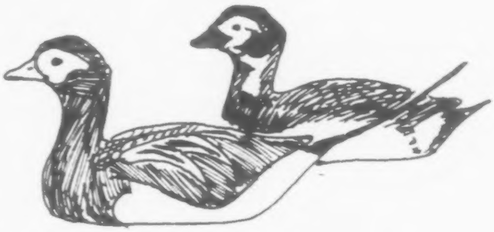
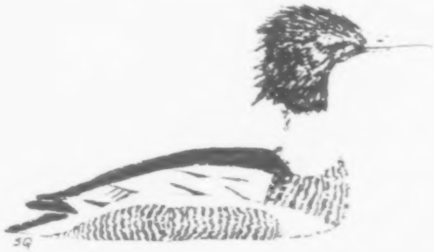
Geese



Length: 65-85 cm Weight: 0.9-7.2 kg

Geese *Anser spp., Branta spp., and Chen spp.* **Animal**

HABITAT: nest on islands and shores of lakes and estuaries particularly in lowland tundra; migrate to wetland areas in the lower 48 for winter
FOODS: leaves, stems, seeds, and roots of grasses, sedges, mosses, and aquatic plants; brant and emperor geese feed on eelgrass and algae in winter
EATEN BY: eggs and young may be eaten by foxes or bears; humans
SYMBIOSES: parasitized by a variety of invertebrate and microscopic organisms
ADAPTATIONS: migrate south to winter in ice free wetlands and coastal areas of North America

Eiders	**Eiders** *Somateria spp. and Polysticta* **Animal**
 Length: 43-61 cm Weight: 0.8-2.2 kg	HABITAT: the 4 species of eiders nest near lowland tundra lakes or on barrier islands, and winter at sea FOODS: in freshwater, eiders feed on aquatic insects and some plants, but at sea they feed on a variety of invertebrate animals (mussels, clams, whelks, seastars, sea urchins, and various crustaceans) EATEN BY: foxes, bears, (eggs only) jaegers and gulls SYMBIOSES: parasitized by a variety of invertebrates and microscopic organisms; often nest in or near arctic terns which harass and drive away some predators ADAPTATIONS: eiders line their nests with their down feathers, thus providing superb insulation for their eggs
Scoters	**Scoters** *Melanitta spp.* **Animal**
 Length: 48-53 cm Weight: 0.7-1.8 kg	HABITAT: alpine and lowland tundra in summer; coastal wetlands in winter FOODS: in summer mainly insect larvae and adults (caddisflies, damselflies, dragonflies, beetles, waterboatmen); at sea they feed mainly on mussels, clams, and other bivalves; also some crustaceans EATEN BY: eggs and young by jaegers, weasels, foxes SYMBIOSES: parasitized by a variety of invertebrate and microscopic organisms ADAPTATIONS: migrate to southern wetlands that are ice-free and to coastal areas
Oldsquaw	**Oldsquaw** *Clangula hyemalis* **Animal**
 Length: 40-57 cm Weight: 0.7-1.0 kg	HABITAT: ponds and lakes of lowland and alpine tundra in summer; at sea in winter FOODS: in freshwater during nesting, oldsquaw feed on larvae of aquatic insects, particularly craneflies; at sea they feed on clams, mussels, and gastropods EATEN BY: eggs and young by foxes, jaegers, falcons SYMBIOSES: parasitized by a variety of invertebrate and microscopic organisms ADAPTATIONS: migrate to coastal areas in the winter
Red-breasted Merganser	**Red-breasted Merganser** *Mergus serrator* **Animal**
 Length: 58 cm Weight: 0.7-1.2 kg	HABITAT: wetlands in tundra, forest, and coastal areas in summer; at sea in winter FOODS: mainly small fish, including sticklebacks EATEN BY: eggs and young may be taken by foxes, bears, jaegers, falcons; young may be taken by northern pike SYMBIOSES: parasitized by a variety of invertebrate and microscopic organisms ADAPTATIONS: migrates from tundra nesting areas to wintering areas in more southern, coastal areas

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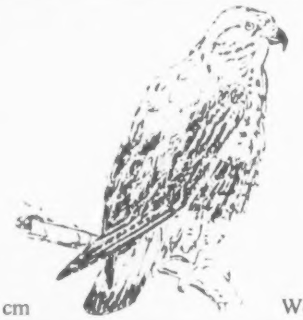
Rough-legged Hawk

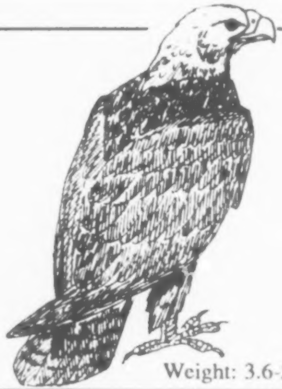


Length: 56 cm Weight: 8.1-1.1 kg

Rough-legged Hawk *Buteo lagopus* **Animal**

HABITAT: alpine and dry lowland tundra near cliffs or river bluffs where it nests; winters in open habitats throughout the Lower 48.
FOODS: lemmings, voles, hares, shrews, ground squirrels; occasionally small birds and insects
EATEN BY: no predators known
SYMBIOSES: parasitized by a variety of invertebrates and microscopic organisms
ADAPTATIONS: migrates from tundra regions to areas with milder winter climates

Golden Eagle

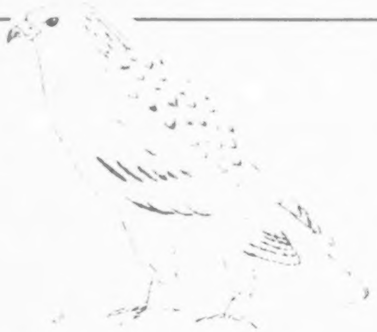


Length: 84-96.5 cm Weight: 3.6-5.8 kg

Golden Eagle *Aquila chrysaetos* **Animal**

HABITAT: alpine tundra
FOODS: tundra hares, marmots, ground squirrels, ptarmigan, and less commonly, the young of large ungulates (caribou, Dall sheep, mountain goats)
EATEN BY: no predators known
SYMBIOSES: parasitized by a variety of invertebrate and microscopic organisms
ADAPTATIONS: migrates from northern to more southern alpine areas for winter

Gyrfalcon

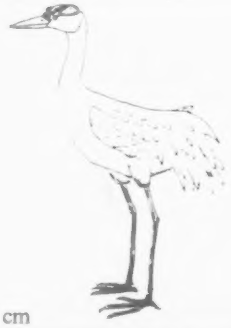


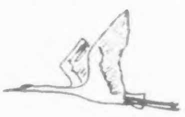
Length: 51-64 cm Weight: 1.2-2.0 kg

Gyrfalcon *Falco rusticolus* **Animal**

HABITAT: alpine tundra near rocky outcrops and cliffs
FOODS: mainly ptarmigan, but also other birds (gulls, jaegers, sandpipers, plovers, snow buntings, longspurs) and some small mammals (lemmings, hares)
EATEN BY: no known predators
SYMBIOSES: parasitized by a variety of invertebrate and microscopic organisms
ADAPTATIONS: since this species' primary prey, ptarmigan, remain in tundra areas and remain active through winter, gryfalcons are also able to do so; some gyrfalcons have white plumage, which may help them surprise their prey, and help reduce heat loss

Sandhill Crane



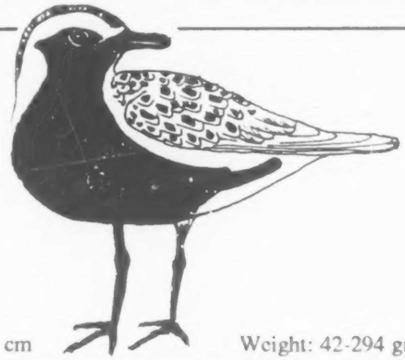


Length: 104 cm Weight: about 2.6 kg

Sandhill Crane *Grus canadensis* **Animal**

HABITAT: lowland tundra, muskegs, and river bottoms throughout Alaska in summer; migrate to plains and coast of the Lower 48 for winter
FOODS: shoots, roots, and seeds of wetland plants, small mammals (lemmings, voles), insects, and frogs
EATEN BY: foxes, wolves, (eggs only) jaegers, gulls
SYMBIOSES: parasitized by a variety of invertebrate and microscopic organisms
ADAPTATIONS: migrates from tundra nesting areas to wintering areas in Lower 48

Plovers

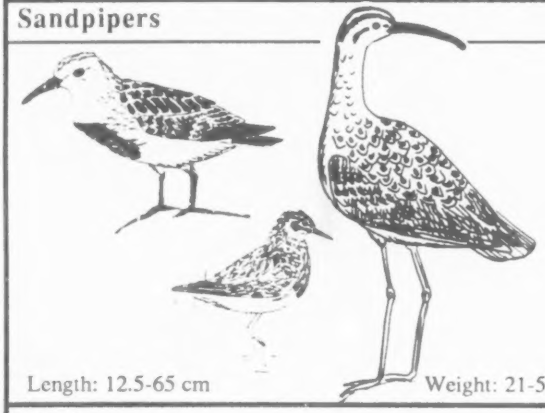


Length: 15-39 cm Weight: 42-294 gm

Plovers *Family: Charadriidae* **Animal**

HABITAT: alpine and lowland tundra in summer; coastal wetlands and prairies in winter
FOODS: adult and larval insects (caterpillars, flies, mosquitos, beetles, and grasshoppers); mollusks, crustaceans, marine worms, and some berries
EATEN BY: jaegers, falcons, arctic foxes, weasels
SYMBIOSES: parasitized by a variety of invertebrates and microscopic organisms; other shorebirds nest near plovers to gain advantage from the watchful plovers' warning cries when predators approach
ADAPTATIONS: plovers migrate from northern tundra nesting areas to southern wintering areas

Sandpipers

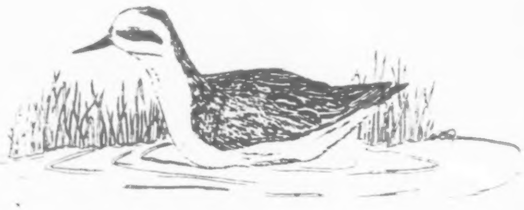


Length: 12.5-65 cm Weight: 21-560 gm

Sandpipers *Family: Scolopacidae* **Animal**

HABITAT: alpine and lowland tundra in summer; coastal wetlands in winter
FOODS: mainly insect larvae and adults, (midges, mosquitos, blackflies, water boatmen, dragonflies, damselflies, craneflies, beetles, mayflies) and a variety of small invertebrate animals (crustaceans, snails, mussels, water mides); less commonly, seeds, and berries
EATEN BY: jaegers, weasels, foxes, falcons
SYMBIOSES: parasitized by a variety of invertebrate and microscopic organisms
ADAPTATIONS: most sandpipers nest on the tundra in the summer then migrate south for winter

Phalaropes

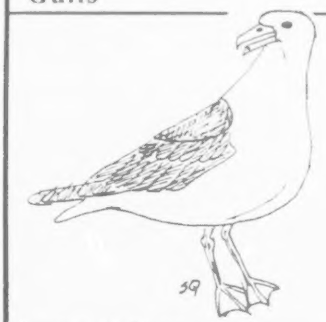


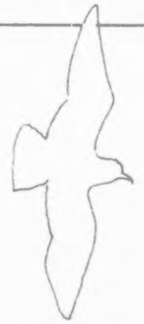
Length: 15-22.5 cm Weight: 28-63 gm

Phalaropes *Phalaropus spp.* **Animal**

HABITAT: ponds and lakes of lowland and alpine tundra in summer; at sea in winter
FOODS: plankton, insect larvae (mosquitos, midges, blackflies, and craneflies), tiny mollusks, amphipods, copepods, fairy shrimp, and other crustaceans
EATEN BY: weasels, foxes, owls, jaegers, falcons
SYMBIOSES: parasitized by a variety of invertebrate and microscopic organisms
ADAPTATIONS: phalaropes migrate from tundra nesting areas to winter at sea along the coasts of North and South America

Gulls



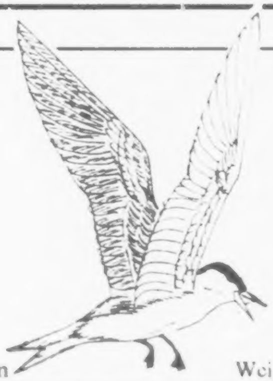


Length: 30-80 cm Weight: 0.2-1.1 kg

Gulls *Family: Laridae* **Animal**

HABITAT: wetlands in tundra, forest and coastal areas
FOODS: mainly dead animals and eggs and young of other birds; also crustaceans, fish, and insects
EATEN BY: eggs and young may be taken by foxes, bears, or jaegers; small gulls may be killed by falcons
SYMBIOSES: parasitized by a variety of invertebrate and microscopic organisms
ADAPTATIONS: a special arrangement of blood vessels in their feet allows them to stand on ice, and still keep their blood warm (counter-current exchange)

Terns

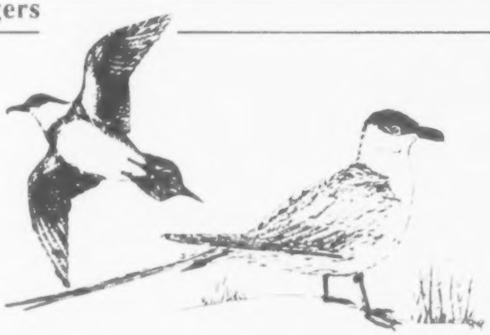


Length: 29-50 cm Weight: 500-1100 gm

Terns *Sterna spp.* **Animal**

HABITAT: wetlands in tundra and forested areas
FOODS: mainly small fish
EATEN BY: falcons; eggs and young by foxes, weasels, bears, and jaegers
SYMBIOSES: a variety of microscopic and invertebrate organisms parasitize terns; terns attack any predators that come near their nesting colonies; other birds, such as eiders, often nest near or in tern colonies, and benefit from the terns' harrassment of potential predators
ADAPTATIONS: terns migrate further than any other animal on earth, from nesting areas in the arctic to wintering areas in the antarctic

Jaegers

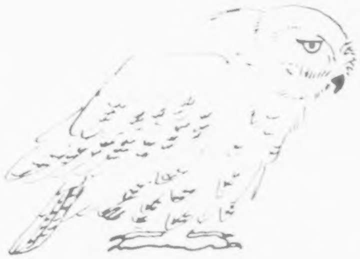


Length: 38-58 cm Weight: 300-1000 gm

Jaegers *Family: Sterocoracidae* **Animal**

HABITAT: alpine and lowland tundra throughout Alaska
FOODS: during nesting, they prey on small birds, lemmings, and eggs of other birds; during other parts of the year they eat small birds and steal fish and crustaceans from other birds
EATEN BY: eggs and young may be eaten by foxes or bears
SYMBIOSES: parasitized by a variety of invertebrate and microscopic organisms
ADAPTATIONS: migrate from tundra nesting areas to wintering areas at sea in both hemisphere

Snowy Owl

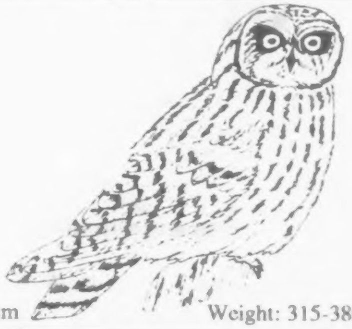


Length: 50-67.5 cm Weight: 1.2-1.9 kg

Snowy Owl *Nyctaea scandiaca* **Animal**

HABITAT: coastal lowland tundra
FOODS: mainly lemmings, and other small mammals, such as voles, shrews, ground squirrels, hares, and weasels
EATEN BY: humans
SYMBIOSES: parasitized by a variety of invertebrate and microscopic organisms
ADAPTATIONS: wanders over large areas of tundra in search of food, and nests only when lemmings are abundant; migrates south in winter only when lemmings are scarce

Short-eared Owl



Length: 32.5-42.5 cm Weight: 315-380 gm

Short-eared Owl *Asio flammeus* **Animal**

HABITAT: tundra and wetlands throughout Alaska
FOODS: small mammals and birds, including voles, shrews, lemmings, young hares, weasels, sparrows, and shorebirds; also large flying insects
EATEN BY: eggs and young may be eaten by foxes or bears
SYMBIOSES: parasitized by a variety of invertebrate and microscopic organisms
ADAPTATIONS: migrate south to winter in prairies and coastal wetlands of the lower 48

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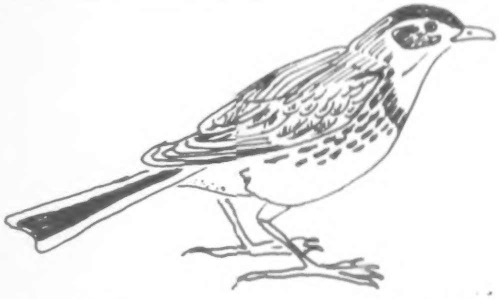
Water Pipit

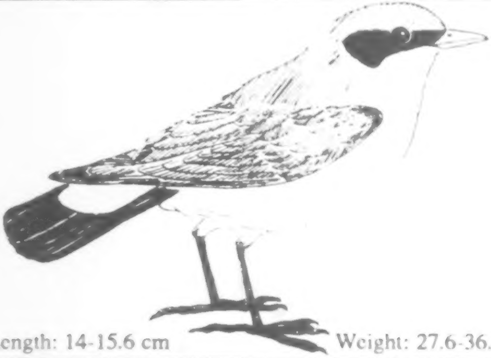


Length: 15-17.8 cm Weight: about 20 gm

Pipits and Wagtails *Family: Motacillidae* **Animal**

HABITAT: alpine and dry lowland tundra
FOODS: insects and small invertebrate animals
EATEN BY: foxes, weasels, jaegers, short-eared owls
SYMBIOSES: parasitized by a variety of invertebrates and microscopic organisms
ADAPTATIONS: nests on or in the ground in the shelter of a rock; migrates to areas with milder climate for winter (wagtails migrate to Asia, while most pipits migrate to the central plains of the lower 48)

Wheatear

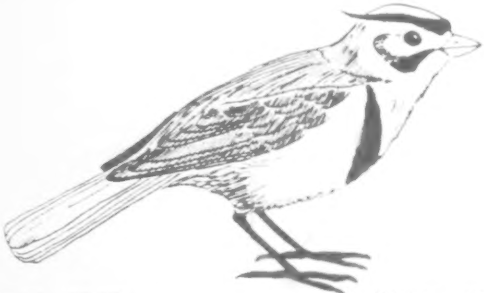


Length: 14-15.6 cm Weight: 27.6-36.8 gm

Wheatear *Oenanthe oenanthe* **Animal**

HABITAT: alpine and dry lowland tundra in summer; coastal wetlands in winter
FOODS: in summer mainly insect larvae and adults, spiders, and other invertebrates
EATEN BY: jaegers, weasels, foxes, short-eared owls
SYMBIOSES: parasitized by a variety of invertebrate and microscopic organisms
ADAPTATIONS: migrates from tundra nesting areas to winter in eastern Asia

Horned Lark

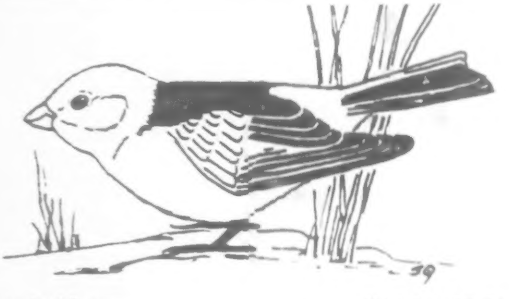


Length: 18-20 cm Weight: 30-32 gm

Horned Lark *Eremophila alpestris* **Animal**

HABITAT: alpine tundra in summer; plains of lower 48 in winter
FOODS: caterpillars, ants, wasps, grasshoppers, leafhoppers, spiders, and other invertebrates in summer; in winter, seeds of various grasses and other plants
EATEN BY: foxes, weasels, jaegers, falcons, short-eared owls
SYMBIOSES: parasitized by a variety of invertebrate and microscopic organisms
ADAPTATIONS: migrates from tundra nesting areas to winter in warmer, more southern prairies; nests on the ground

Snow Bunting

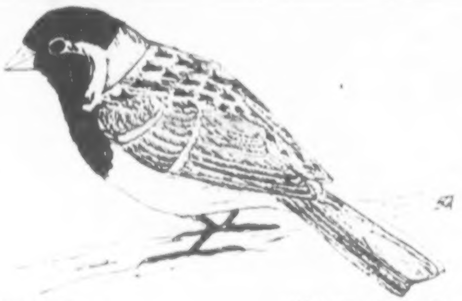


Length: 15 cm Weight: 32-34 gm

Snow Bunting *Plectrophenax nivalis* **Animal**

HABITAT: alpine and lowland tundra throughout Alaska in summer; some remain throughout winter, but most migrate to central plains of the lower 48
FOODS: mainly seeds and buds of tundra plants
EATEN BY: foxes, weasels, jaegers, short-eared owls
SYMBIOSES: parasitized by a variety of invertebrate and microscopic organisms
ADAPTATIONS: migrates from tundra nesting areas to wintering areas in central plains; avoids severe cold and windby nesting in sheltered spots, and by burrowing into snow; often nests in oil drums, buildings, and boxes abandoned by humans

Lapland Longspur

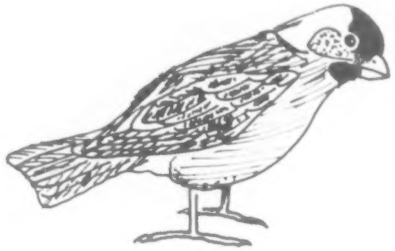


Length: 16 cm Weight: about 28 gm

Lapland Longspur *Calcarius lapponicus* **Animal**

HABITAT: alpine and dry lowland tundra
FOODS: mainly seeds and buds of plants; also insects
EATEN BY: weasels, foxes, jaegers, gulls, short-eared owls
SYMBIOSES: parasitized by a variety of microscopic and invertebrate organisms; longspurs line their nests with caribou hair or ptarmigan feathers
ADAPTATIONS: longspurs nest in tundra areas, but migrate to warmer, more southern prairies for winter

Rosy Finch

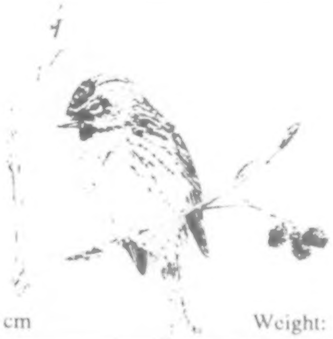


Length:16 cm Weight: 27-32 gm

Rosy Finch *Leucosticte arctoa* **Animal**

HABITAT: alpine tundra
FOODS: seeds of alpine tundra plants; also insects
EATEN BY: weasels, foxes, jaegers, short-eared owls, falcons
SYMBIOSES: a variety of invertebrate and microscopic organisms parasitize rosy finches
ADAPTATIONS: migrate from alpine tundra nesting areas to wintering areas at lower elevations or alpine areas further south

Redpolls

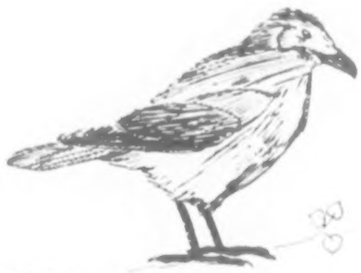


Length: 12.7-14 cm Weight: 13-19 gm

Redpolls *Carduelis spp.* **Animal**

HABITAT: nests in alpine and lowland tundra areas with low shrubs; winter in boreal forest
FOODS: seeds of willows, dwarf birch, and other tundra plants; also insects
EATEN BY: weasels, foxes, jaegers, short-eared owls
SYMBIOSES: parasitized by a variety of invertebrate and microscopic organisms
ADAPTATIONS: redpolls wander over vast expanses of tundra and boreal forest in search of areas with abundant food; they often burrow into snow drifts to avoid cold and wind

Common Raven



Length:61 cm Weight: 1.1-1.4 kg

Common Raven *Corvus corax* **Animal**

HABITAT: tundra, wetlands, and forests throughout Alaska
FOODS: scavenges meat from kills of large predators; also eggs and young of other birds, small mammals, berries, plant roots and any other food it can find
EATEN BY: eggs and young may be eaten by eagles
SYMBIOSES: parasitized by a variety of invertebrate and microscopic organisms; ravens feed on the scraps left by wolves, bears, other predators, and humans
ADAPTATIONS: ravens change their food habits according to the availability of different kinds of food; they also follow predators

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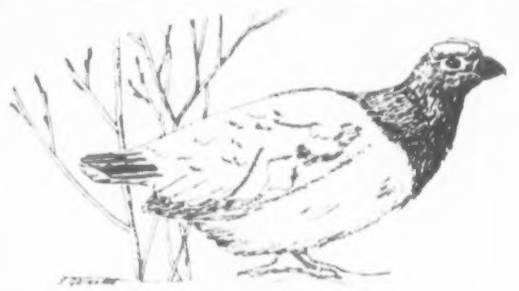
Ptarmigan

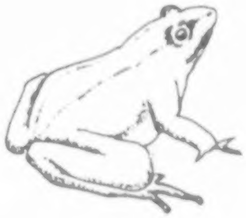


Length: 32-38 cm Weight: 330-675 gm

Ptarmigan *Lagopus spp.* **Animal**

HABITAT: alpine and dry lowland tundra
FOODS: mainly buds and twigs of willow, dwarf birch, and other shrubs, also seeds, berries, and some insects
EATEN BY: foxes, weasels, gyrfalcons, golden eagles, humans
SYMBIOSES: a variety of microscopic and invertebrate organisms parasitize ptarmigan
ADAPTATIONS: ptarmigan have fully feathered feet; these provide insulation and "snowshoes" that allow ptarmigan to walk on the snow surface; ptarmigan often roost in snow banks to keep warm; their dense feathers and down provide excellent insulation against the cold

Wood Frog



Length:up to 6.5 cm (body only) Weight: unknown

Wood Frog *Rana sylvatica* **Animal**

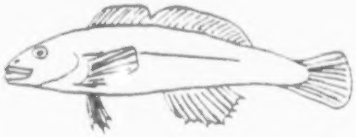
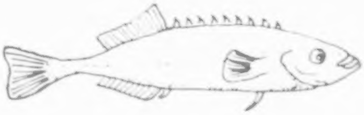
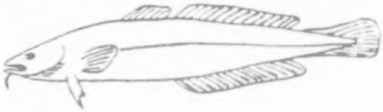
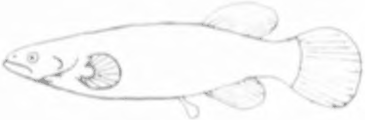
HABITAT: tundra, muskegs, and forests; eggs and tadpoles live only in water; adults live on land
FOODS: adults eat insects, including flies, true bugs, lacewings, dragonflies, and others; tadpoles eat algae and small aquatic animals
EATEN BY: tadpoles are eaten by fish, dragonfly larvae, loons and grebes; adults are eaten by sandhill cranes, ravens, and other omnivores
SYMBIOSES: parasitized by certain invertebrate and microscopic organisms
ADAPTATIONS: wood frogs produce antifreezes in their bodies and hibernate during winter beneath dry soil and plant litter

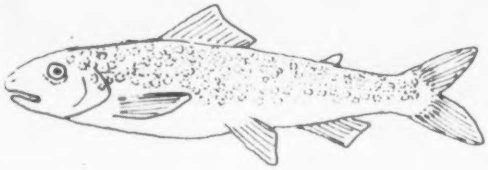
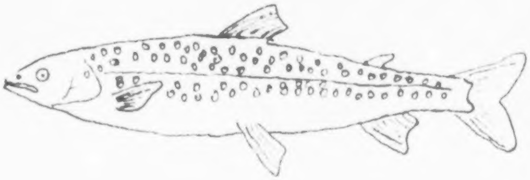
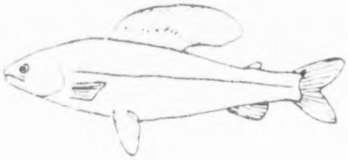
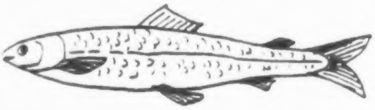
Water

Air

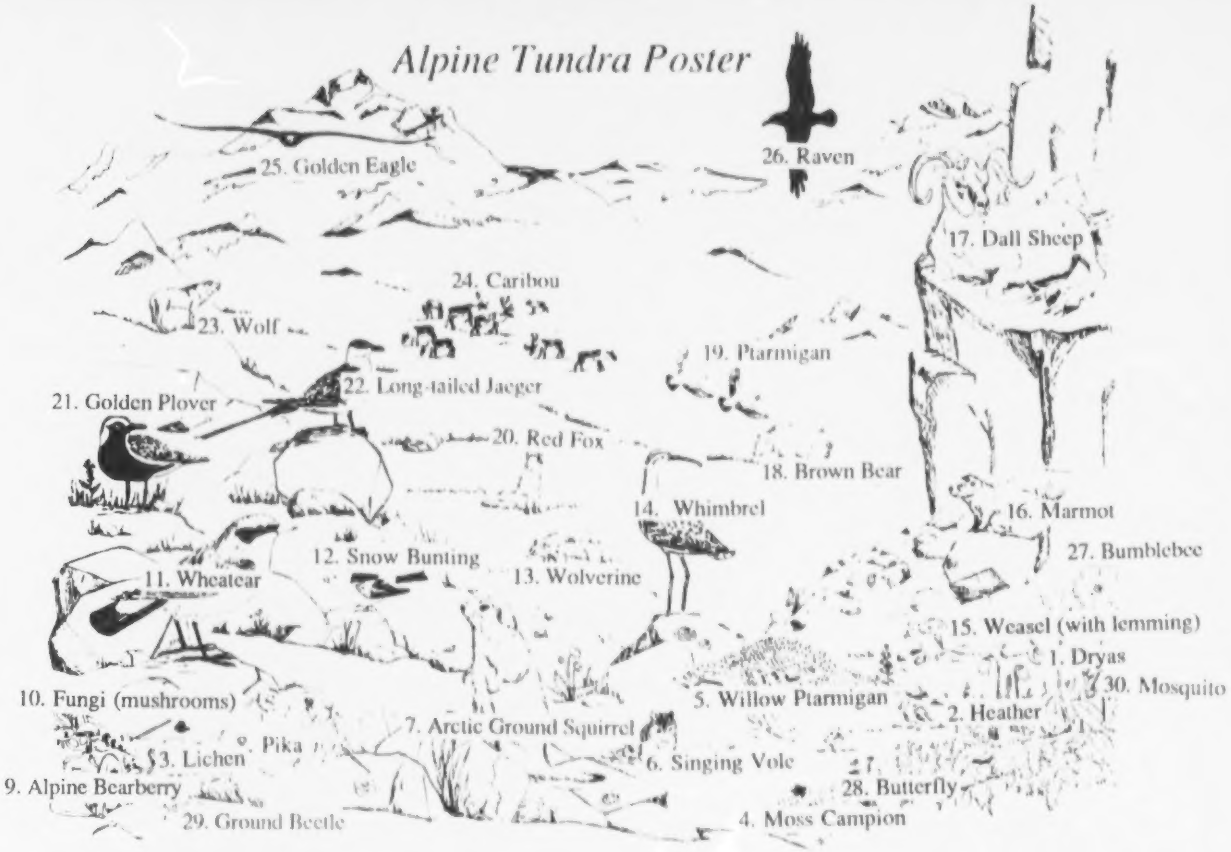
Rocks and Soil

Sunlight (and other forms of energy)

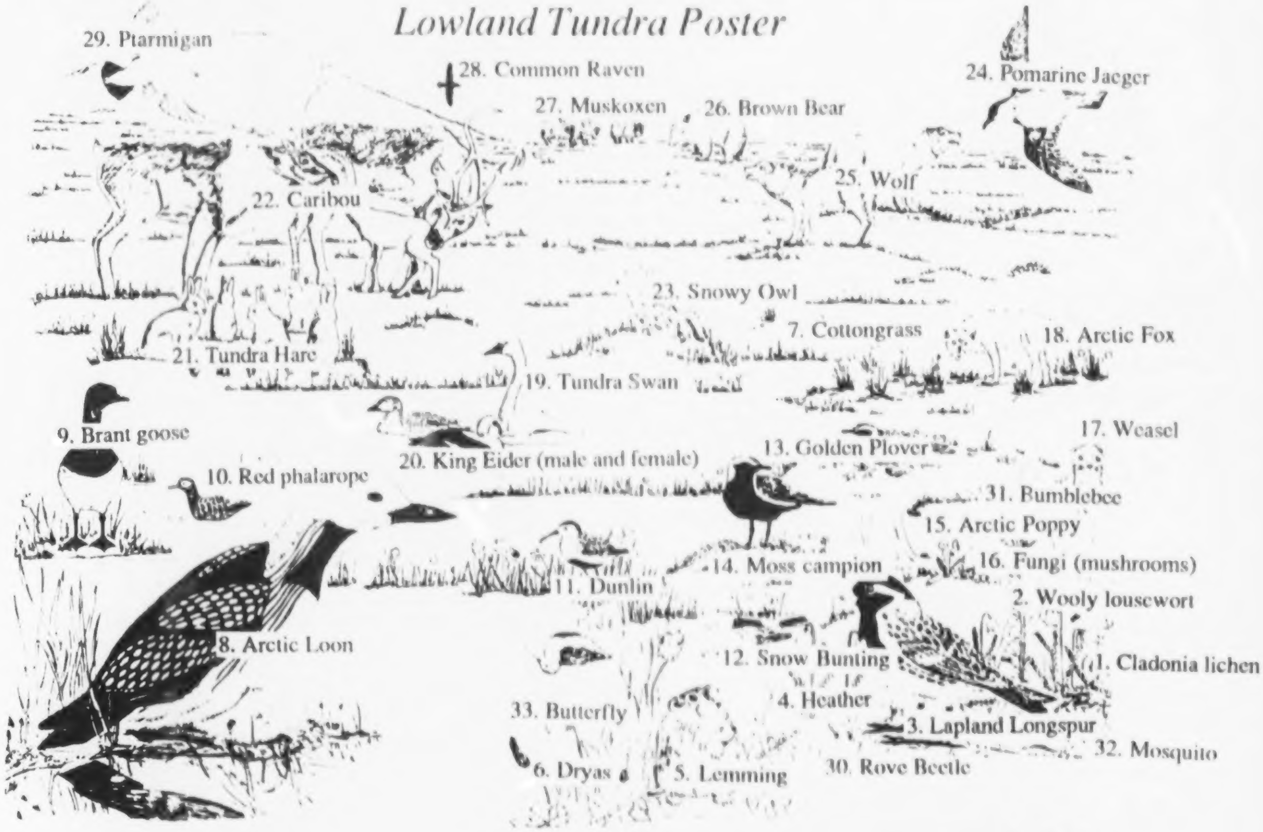
Slimy Sculpin	**Slimy Sculpin** *Cottus cognatus* **Animal**
 Size: up to 12 cm	HABITAT: adults live on the bottoms of lakes and fast moving streams; may move into shallow water to spawn FOODS: mainly larvae of flies, such as mayflies, caddisflies, midges, craneflies; also dragonflies and amphipods; small fish and aquatic vegetation EATEN BY: other fish, such as lake trout, burbot, and grayling; loons, grebes SYMBIOSES: parasitized by tapeworms and nematodes ADAPTATIONS: the color and pattern of their skins makes them nearly invisible when motionless on the bottom
Nine-spine Stickleback	**Nine-spine Stickleback** *Pungitius pungitius* **Animal**
 Size: up to 7.5 cm	HABITAT: found around the world in lakes and rivers of northern regions; spend the winter in deep water, then migrate to shallow water and up tributaries to spawn FOODS: midges, water fleas, copepods, crustaceans, and other aquatic insects EATEN BY: arctic charr, lake trout, grayling, burbot, loons, grebes, terns, gulls SYMBIOSES: unknown ADAPTATIONS: sticklebacks can survive underneath the ice in winter because they migrate to deep water, and can tolerate water with a very low oxygen content
Burbot	**Burbot** *Lota lota* **Animal**
 Size: up to 122 cm	HABITAT: prefer to live near the bottom of deep lakes and streams; they spawn in moderately deep water with clean gravel and sand bottoms FOODS: young feed mostly on invertebrates; adults feed mostly on fish including sculpins, grayling, lake trout, and sticklebacks; also feed occasionally on voles, shrews,and small birds EATEN BY: other fish, such as lake trout; humans SYMBIOSES: parasitized by nematodes and tapeworms ADAPTATIONS: burbot are able to survive arctic winters because they live in deep waters that do not freeze solid in winter and are tolerant of icy cold water; very adaptable in feeding habits
Blackfish	**Blackfish** *Dallia pectoralis* **Animal**
 Size: up to 20-30 cm	HABITAT: lives in heavily vegetated lowland ponds and streams mainly in interior and southwestern Alaska; move into deep water for winter FOODS: aquatic insect larvae, including midges, mayflies, dragonflies, and stoneflies; also water fleas, segmented worms, and algae EATEN BY: mink, loons, grebes, terns, humans SYMBIOSES: parasitized by nematodes and tapeworms ADAPTATIONS: blackfish are able to breathe air for short periods of time and make antifreezes which allow them to tolerate icy cold water; they are also able to survive partial freezing.

Lake Trout	**Lake Trout** *Salvelinus namaycush* **Animal**
 Length: mature at 25-50 cm; up to 120 cm	HABITAT: throughout northern North America; primarily in cold lakes at high altitudes or latitudes and occasionally in streams FOODS: varies with age; young eat adult and larval insects (including midges, craneflies); older lake trout eat fish such as sticklebacks and whitefish; size of fish eaten increases with size of lake trout EATEN BY: young are eaten by other fish, terns, grebes, and loons; adults by humans SYMBIOSES: parasitized by tapeworms and nematodes; variety of ectoparasites possible ADAPTATIONS: unknown
Arctic Charr	**Arctic Charr** *Salvelinus alpinus* **Animal**
 Length: mature at 10-50 cm; up to 96 cm	HABITAT: arctic and subarctic lakes and rivers FOODS: varies with age; more invertebrates when young and more fish when older; variety of aquatic insects, including midges and other flies; small fish, such as sticklebacks EATEN BY: diving birds, other fish, and humans SYMBIOSES: parasitized by nematodes and tapeworms ADAPTATIONS: arctic charr eggs and young are able to survive near-freezing water temperatures; in some areas migrate to saltwater when 2-3 years old during the summer to feed in rich nearshore waters then return to freshwater to overwinter and spawn; allows fish to grow faster and larger
Arctic Grayling	**Arctic Grayling** *Thymallus arcticus* **Animal**
 Length: mature at 25-27 cm; up to 35 cm	HABITAT: Grayling live in cold, clear streams, lakes and ponds of northern North America, northern Asia and Siberia; they spawn in streams with sandy, gravel bottoms FOOD: mostly insects, such as midges, mayflies, stoneflies, cranflies, mosquitos, and small fish EATEN BY: young are eaten by fish-eating birds, and other fish; adults are eaten by humans SYMBIOSES: parasitized by tapeworms and nematodes ADAPTATIONS: Grayling migrate from small tributaries into deep water to spend the winter; this allows them to live in the summer in streams and ponds that freeze solid in winter.
Whitefish	**Whitefish** *Subfamily: Coregoninae* **Animal**
 Length: (varies by species) 35-70 cm	HABITAT: Different species prefer different habitats, but all are found in lakes or streams FOODS: mainly insects, including larval mayflies, stoneflies, midges, dragonflies, mosquitos, and others; eggs and larvae of other fish, such as lake trout, burbot EATEN BY: lake trout, burbot, arctic charr, humans SYMBIOSES:parasitized by tapeworms and nematodes ADAPTATIONS: some migrate as juveniles to saltwater during the summer to feed in rich nearshore waters then return to freshwater to overwinter and spawn; allows fish to grow faster and larger; some move to deep lakes to overwinter

Alpine Tundra Poster


25. Golden Eagle
26. Raven
17. Dall Sheep
24. Caribou
23. Wolf
19. Ptarmigan
22. Long-tailed Jaeger
21. Golden Plover
20. Red Fox
18. Brown Bear
14. Whimbrel
16. Marmot
27. Bumblebee
12. Snow Bunting
13. Wolverine
11. Wheatear
15. Weasel (with lemming)
1. Dryas
30. Mosquito
10. Fungi (mushrooms)
5. Willow Ptarmigan
2. Heather
7. Arctic Ground Squirrel
8. Pika
3. Lichen
6. Singing Vole
9. Alpine Bearberry
28. Butterfly
29. Ground Beetle
4. Moss Campion

Lowland Tundra Poster


29. Ptarmigan
28. Common Raven
24. Pomarine Jaeger
27. Muskoxen
26. Brown Bear
22. Caribou
25. Wolf
23. Snowy Owl
7. Cottongrass
18. Arctic Fox
21. Tundra Hare
19. Tundra Swan
9. Brant goose
17. Weasel
13. Golden Plover
20. King Eider (male and female)
10. Red phalarope
31. Bumblebee
15. Arctic Poppy
16. Fungi (mushrooms)
14. Moss campion
11. Dunlin
2. Wooly lousewort
8. Arctic Loon
12. Snow Bunting
1. Cladonia lichen
4. Heather
33. Butterfly
3. Lapland Longspur
32. Mosquito
6. Dryas
5. Lemming
30. Rove Beetle

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TUNDRA ADAPTATION CARDS

This mammal has long, dense fur. It has fairly short ears. It turns white in winter.

This mammal has short fur. It has very large ears. It loses a lot of heat through these ears, particularily on cool days. It stays light brown in color throughout the year.

This bird feeds mainly on grasses and sedges. Its large webbed feet allow it to walk across wet ground and swim on the surface of ponds and lakes.

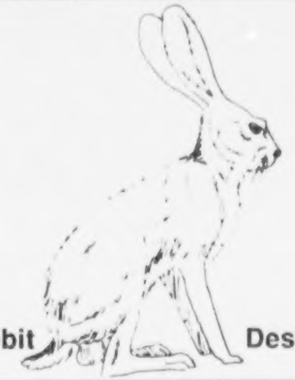
This bird has a specially shaped bill that helps it take seeds out of the cones of spruce trees. It has long narrow toes that can hold on to small branches.

This large insect is covered by a soft velvet fur. This fur traps heat made by the muscles of the insect.

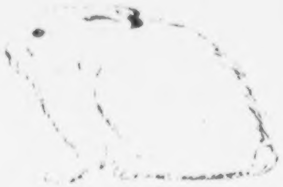
The body of this small insect is covered by a thin coat of fine hairs.

This plant depends on the wind to carry its pollen.

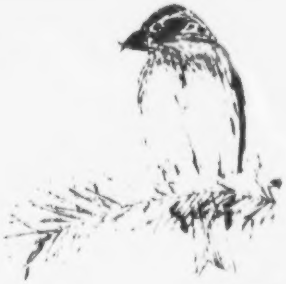
This plant depends upon hummingbirds to carry its pollen.



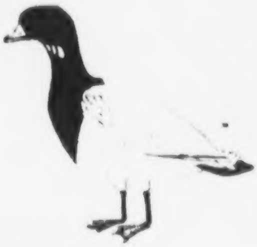
Desert Jackrabbit Desert



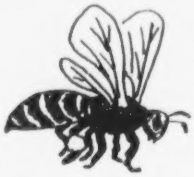
Snowshoe Hare Tundra



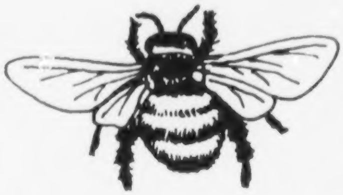
Crossbill Spruce Forest



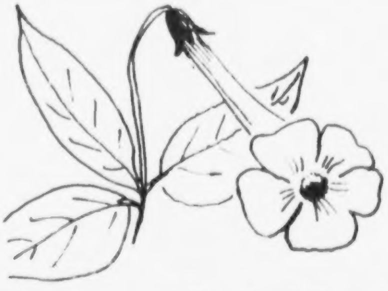
Brant Goose Tundra



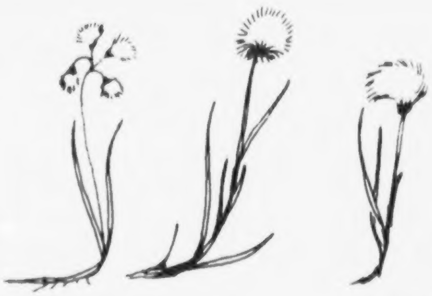
Honeybee Forest, Desert



Bumblebee Tundra



Trumpet Flower Tropical Forest



Cottongrass Tundra

TUNDRA ADAPTATION CARDS

This mammal has long white fur. It has sharp hooves that are soft in the center. These help it get firm footholds on steep slopes and cliffs.

This mammal has a thick layer of fat which keeps it warm even at very cold temperatures. Its body is long and round. It has no outer ears. Its fore and hind limbs are short, and flattened. It can not move quickly on land.

This 8-13 inch long mammal has thick fur. It may weigh 1000 gms. In winter it has a thick layer of fat underneath its fur coat. It can hibernate for several months. During hibernation it lives off of the energy and water in its stored fat, so it doesn't need to eat or drink. It digs underground burrows.

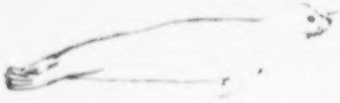
This 6 inch long mammal has short fur and a fairly long tail. It weighs about 90 grams. It must eat food throughout the year, but it can survive for weeks without drinking any water. It can be active at temperatures up to 107° F without getting too hot. It digs underground burrows.

The long, soft fur of this animal is sometimes 24 inches (60 cm) long. This long fur nearly hides the short legs, tails, and ears of this large animal. This animal has hooves and large horns.

This animal has short hair and a long tail. It is a large animal with wide hooves. It has large horns on its head.

This plant grows just a few inches tall. Its small white flowers are shaped like bells. This helps them trap sunlight heat, and shelters their seed-making parts from wind. Its leaves are small and thick. The leaves are covered with a wax-like coating that prevents them from drying out in the wind.

This plant grows quite tall. Its large leaves point downward and have small, narrow tips. This shape helps water run off the leaf.

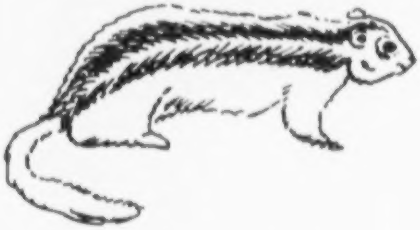


Harbor Seal

Ocean

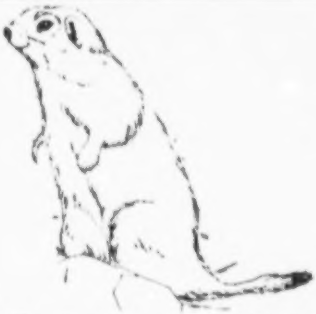
Mountain Goat

Alpine Tundra



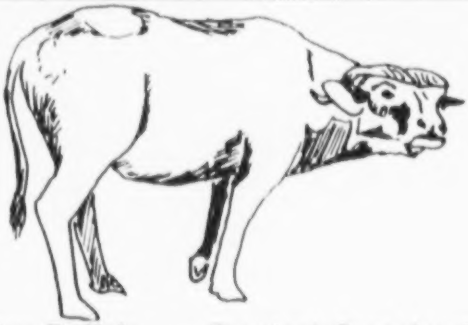
Antelope Ground Squirrel

Desert



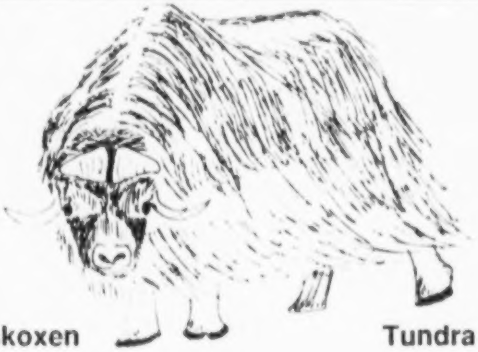
Arctic Ground Squirrel

Tundra



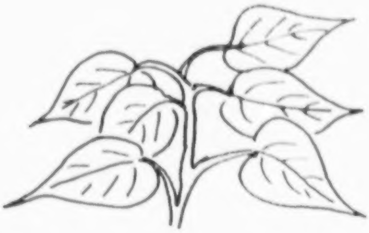
Water Buffalo

Tropical Grasslands



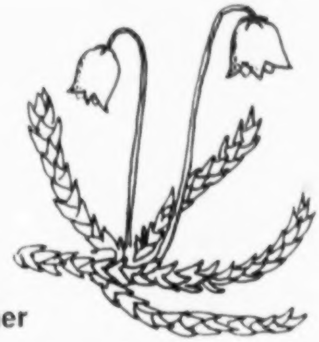
Muskoxen

Tundra



Philodendron

Tropical Forest



Heather

Tundra

TUNDRA ADAPTATION CARDS

This mammal has large hooves that help support its weight on wet, soggy ground and crusty snow. Its long legs allow it to run quickly in wide open spaces. It can use its large hooves as shovels to paw through snow to uncover plants.

This mammal has small hooves and long muscular legs. These traits allow it to run quickly, make sharp turns, and leap over obstacles.

This bird has feathers all over its feet. These feathers keep its feet warm and act like a pair of snowshoes in winter. This animal turns white in winter.

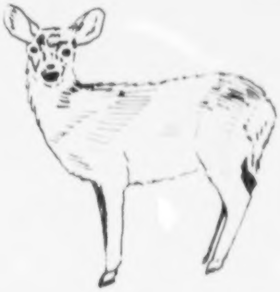
This bird's feet are not covered by fur or feathers. It can not walk across the snow. It stays the same color throughout the year.

This small animal has long, warm fur. It turns white in winter. It has short ears. It weighs 7-15 pounds.

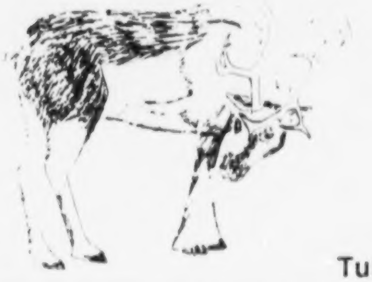
This small animal has short fur. It is light brown all year round. It has large ears. It weighs 3-6 pounds.

This bird has a thick layer of soft feathers, called down. The down traps air and allows this bird to stay warm even in icy cold water.

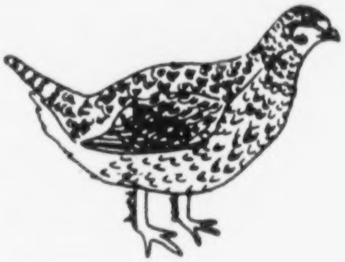
This bird has long legs and large webbed feet with claws for perching on tree branches.



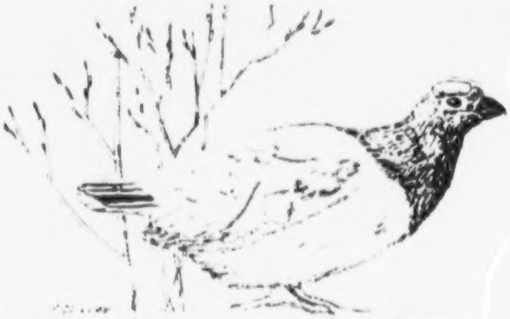
Deer **Forest**



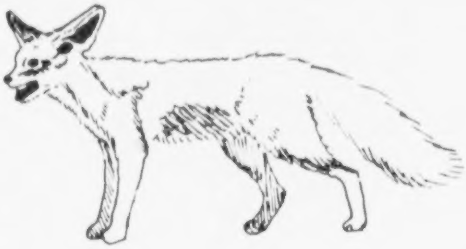
Caribou **Tundra**



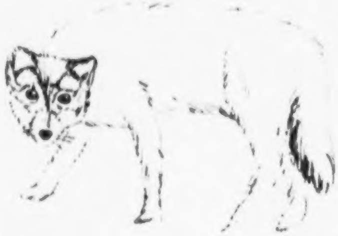
Sharp-tailed Grouse **Prairie**



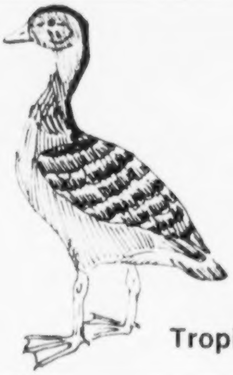
Ptarmigan **Tundra**



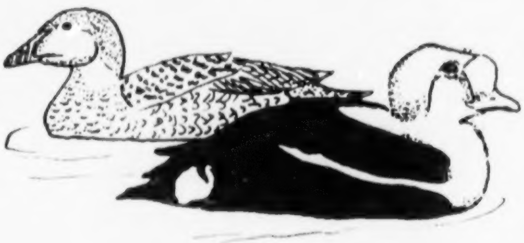
Kit Fox **Desert**



Arctic Fox **Tundra**



Tree Duck **Tropical Forest**



King Eider **Tundra**

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TUNDRA ADAPTATION CARDS

This small mammal has thick fur. It has a short tail, small ears, and short legs. Each winter this mammal grows large claws on its front toes. These claws help it dig tunnels through snow. It turns white in winter.

This small mammal has short fur. It has long ears, a long tail, and long legs. It stays a light tan color year-round. It stays underground during the day. It is active at night.

This large white bird feeds on small mammals. It nests on the ground.

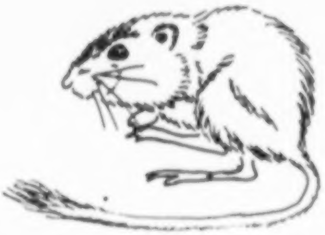
This large brown bird feeds on small mammals. It builds large stick nests in trees.

This small bird has long wings and a small body. It is able to fly thousands of miles each year. It eats insects.

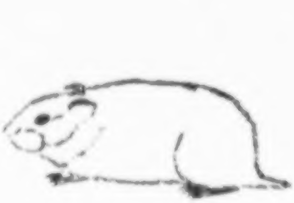
This small bird has short wings. It flys well, but only for short distances. It feeds on insects.

This plant has large flowers that turn so they always face the sun. The yellow petals reflect light toward the center of the flower. This helps warm the the parts of the flower that form its seeds.

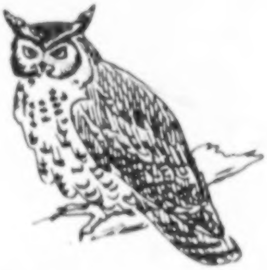
This plant has white flowers that bloom only at night.



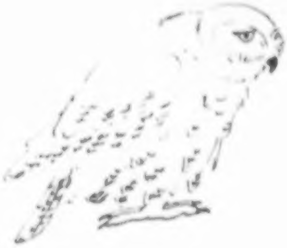
Kangaroo Rat **Desert**



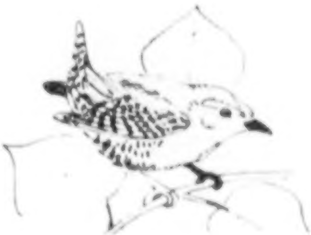
Collared Lemming **Tundra**



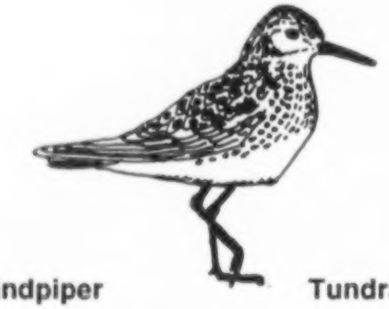
Great Horned Owl **Forest**



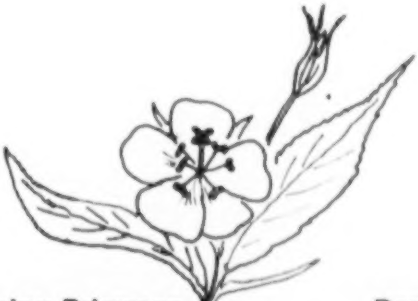
Snowy Owl **Tundra**



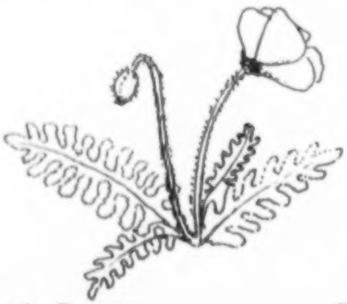
Winter Wren **Forest**



Baird's Sandpiper **Tundra**



Evening Primrose **Desert**



Arctic Poppy **Tundra**

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